THE

JOURNAL

THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

JANUARY 1910

MEETINGS OF THE SOCIETY: NEW YORK, JANUARY 11; ST. LOUIS, JANUARY 15; BOSTON, JANUARY 21. SPRING MEETING, ATLANTIC CITY, MAY 31 TO JUNE 3. LONDON MEETING, JULY 26 TO 29

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THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 JANUARY 1910 NUMBER 1

THE New York monthly meeting of the Society will be held in the Engineering Societies' Building on Tuesday evening, January 11. The subject for discussion is Lubrication. The paper upon Efficiency Tests of Lubricating Oils by Prof. F. H. Sibley of the University of Alabama, published in The Journal for November, will be presented and important contributions upon the properties of lubricants, their efficiency, durability, characteristics, etc., will be made by Dr. C. F. Mabery, of Case School, Cleveland, and Genl. Chas. Miller of Franklin, Pa.

Dr. Mabery has been engaged for a long period of time in experiments upon lubricating oils and has obtained results of unusual interest, because of the uniformity attained in repeating experiments, always a difficult matter in testing lubricants. General Miller has been so long identified with the subject of lubrication and has so large a fund of information as a result of this experience that his remarks will add greatly to the interest of the evening. There will be discussions also by F. R. Low, Editor of Power, I. E. Moultrop, mechanical engineer of the Boston Edison Company, J. P. Sparrow, chief engineer of the New York Edison Company, and others.

The subject of lubrication is so important in its bearing upon the conservation of power and upon machinery of all kinds, especially since the introduction of recent new types, such as the steam turbine and automobile, that it is desirable to have authentic information easily available for the use of engineers. By introducing the subject for discussion before the Society, it is hoped that this result may eventually be brought about and that a substantial beginning will be made at this meeting.

MEETING IN ST. LOUIS, JANUARY 15

The next monthly meeting of the Society in St. Louis will be held on January 15. The usual announcement of this meeting with details in regard to the paper and discussion will be sent to members and engineers in St. Louis and vicinity previous to the meeting.

MEETING IN BOSTON, JANUARY 21

A joint meeting of The American Society of Mechanical Engineers, the Boston Society of Civil Engineers and the Boston branch of the American Institute of Electrical Engineers, will be held in Boston on the evening of January 21. Committees have been appointed by the society of civil engineers and the local section of the electrical engineers to coöperate with the local committee of this Society to complete arrangements. The meeting will take the form of a banquet and reception, with the presidents of the three societies in attendance, George H. Westinghouse of The American Society of Mechanical Engineers, L. B. Stilwell of the American Institute of Electrical Engineers and George B. Francis of the Boston Society of Civil Engineers, besides the incoming president of the American Society of Civil Engineers, John A. Bensel, and other distinguished guests. The banquet hall of the Hotel Somerset, which is the largest and finest in the city has been engaged for the occasion.

Following the banquet there will be addresses by some of the guests and a paper on the Main and Auxiliary Machinery of the Battleship North Dakota, illustrated with lantern slides, by Charles B. Edwards of the Fore River Shipbuilding Company. There is under discussion at Boston a project for building and equipping a united engineering building and the president of the Boston Society of Civil Engineers will bring up this subject and describe what efforts that Society has already made towards this end.

The meetings of The American Society of Mechanical Engineers in Boston have been uniformly well attended, as have those of the other societies, and it is believed that this joint meeting will bring together an unusually large number of engineers and that it will be the most successful similar meeting of the kind that has taken place in that city.

SPRING MEETING, ATLANTIC CITY, MAY 31–JUNE 6

The Spring Meeting of The American Society of Mechanical Engineers will be held this year as usual, in addition to the London Meet-

ing which occurs in July. Atlantic City has been selected by the Meetings Committee and approved by the Council as the place and the time will be from May 31–June 6, inclusive. The headquarters during the meeting will be at the Marlborough-Blenheim Hotel.

JOINT MEETING OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND THE INSTITUTION OF MECHANICAL ENGINEERS

In response to the invitation of The Institution of Mechanical Engineers of Great Britain, received and accepted by The American Society of Mechanical Engineers, and recently sent out to the general membership, 133 members and 100 ladies have signified their intention of attending the joint meeting in Great Britain in the summer of 1910, and 183 have expressed themselves as giving the matter favorable consideration.

The present indications are that some of the functions will be held in Manchester, Birmingham or Sheffield, possibly concluding in London, and the invitation itself is an earnest of the notable professional and social opportunities which will be extended to the Society. Arrangements will probably be made for the accommodation of the members on the same steamer.

Where time and personal engagements permit, the visiting members will have the opportunity of attending the following events and meetings which are to take place during the summer of 1910: Anglo-Japanese Exhibition at Sheperds Bush, London; American Exposition in Berlin; Brussels Universal and International Exhibition; London Pageant, probably at Chester; Pageant at Bristol; Church Pageant at Fulham Palace; Military Pageant in London; International Congress of Mining, Metallurgy, Applied Mechanics and Practical Geology, at Düsseldorf; International Sports Exhibition at Vienna; International Exhibition of Arts and Industries, Alexandra Palace, London; the Passion Play at Oberammergau.

It is expected that papers will be presented by members of both societies on electrification of railways, on round house practice and the handling of locomotives at terminals, on certain phases of machine shop practice, and on the subject of standards for gear teeth which is now being considered by a committee of this Society as well as by a committee of the Institution of Mechanical Engineers. While papers will be mainly restricted to the subjects indicated, the Meetings Committee will be pleased to consider papers on other subjects.

REPORTS OF MONTHLY MEETINGS

BOSTON MEETING, NOVEMBER 17

A very successful meeting of the Society was held at Boston in the Lowell Building, Massachusetts Institute of Technology, Wednesday evening, November 17. Two hundred and forty were present at this meeting and the Low-pressure Steam Turbine was the topic of discussion.

Mr. Henry G. Stott of the Interborough Rapid Transit Company gave an interesting account of the difficulties encountered as well as the very fine results obtained from an installation recently made at the 59th Street Station of his company, New York. Mr. W. L. R. Emmet described the low-pressure turbine situation from his viewpoint and pointed out the advantages of this type of prime mover for many mill installations and industrial works in New England. Mr. H. E. Longwell, consulting engineer of the Westinghouse Machine Company, and Edward L. Clark, manager of their Boston office, both spoke on the work that company are doing in this field. Mr. Max Rotter, turbine engineer of the Allis-Chalmers Company, pointed out in a humorous way a number of situations where the low-pressure turbine was not a desirable proposition. Professor Miller of the Massachusetts Institute of Technology also discussed the subject.

BOSTON MEETING, DECEMBER 17

On Friday evening, December 17, a goodly number of engineers of Boston and vicinity gathered at the call of the local members of The American Society of Mechanical Engineers to discuss the Effect of Superheated Steam on Cast Iron. The meeting was called to order by Prof. Ira N. Hollis, who announced that the next meeting would be held on January 21 and would take the form of a reception, possibly a complimentary dinner, to the newly elected president of the American Society, George H. Westinghouse, and other of the Society's officials. A later announcement of this meeting is contained elsewhere in this number, and of the coöperation of the Boston Society

of Civil Engineers and of the local members of the Institute of Electrical Engineers. The committee which has been in charge of the meetings, consisting of Messrs. Hollis, Moultrop, Miller, Mann and Libbey, was continued.

The set papers which were published in the December issue of The Journal were then presented by their authors—Prof. Edward F. Miller of Boston, Arthur S. Mann of Schenectady, and Prof. Ira N. Hollis of Boston in the order named, and were discussed by Messrs. Collins of Stone & Webster, George A. Orrok of the New York Edison Company, Chas. H. Bigelow of Chas. T. Main's office, W. K. Mitchell of Philadelphia, Messrs. Primrose and Nutting of the Power Specialty Company, Wm. E. Snyder of the American Steel and Wire Company and others. The general purport of the discussion, was rather reassuring to the users of cast iron pipe and fittings, and to those who are interested in the extension of the use of superheated steam, in indicating that superheated steam *per se* has no injurious effect upon cast iron fittings, but that if the pipe lines are properly designed for the greater ranges of temperature, if the fittings are made adequate to the pressure and if fluctuations in temperature can be avoided, the use of superheated steam introduces no piping difficulties which can not be easily overcome.

MEETING AT ST. LOUIS, NOVEMBER 13

At the meeting of the Society at St. Louis, November 13, with the Engineers' Club at St. Louis, a description of the new plant of the Heine Safety Boiler Company of Boston was presented by E. R. Fish, under the title, A Modern Boiler Shop. There was also further discussion of Professor Carpenter's paper on High-Pressure Fire Service, continued from the October meeting.

MEETING AT ST. LOUIS, DECEMBER 11

A meeting was held with the Engineers' Club of St. Louis on Saturday evening, December 11, at the rooms of the latter society. The meeting was called to order by William H. Bryan, member of the Meetings Committee of the Society and chairman of the joint committee of the two societies at St. Louis. Prof. E. L. Ohle acted as secretary. There were present fifty-five members and guests.

The paper of the evening was by G. R. Parker of the General Electric Company, on The Relation of the Steam Turbine to Modern

Central Station Practice, in which the underlying principles of modern steam turbines were discussed, together with the design of various prominent types on the market, and the developments made in recent years in improving capacity and efficiency. Attention was called to the large turbine capacity which may now be obtained within limited floor space; to the question of low-pressure turbines and their availability in supplementing standard reciprocating engines, increasing both their capacity and economy; also to the work already done in this direction at the plant of the Union Electric Light & Power Company in St. Louis, and to prospective work along similar lines in the same plant. The address was illustrated by lantern slides.

Discussions followed by Chairman Bryan, Prof. H. W. Hibbard, L. R. Day, E. R. Smith and Prof. E. L. Ohle, in which many additional interesting points were brought out.

On the afternoon of the day of the meeting an excursion was made to the Ashley Street plant of the Union Electric Light & Power Company, for the inspection of the apparatus and equipment, on the invitation of John Hunter, chief engineer. This excursion, supplementing as it did the paper of the evening, added much to the interest and value of the meeting and a vote of thanks was extended to Mr. Hunter for the opportunity so generously afforded.

THE ANNUAL MEETING

The thirtieth annual meeting of The American Society of Mechanical Engineers was held in the Engineering Societies Building December 7 to 10, with an attendance of 628 members and 435 guests. This year, for the first time, the arrangements of the entertainment features were entirely in the hands of the local committee, the members in New York and vicinity acting as hosts, and the results fully justified this method of handling an important part of the annual meeting.

Despite the severe storm on Tuesday evening, the President's reception was well attended, and a large audience gathered in the auditorium. On Wednesday afternoon the trip through the Pennsylvania Terminal brought out a large body of members and guests, and in the evening L. W. Ellis, of the Bureau of Plant Industry, U. S. Dept. of Agriculture, delivered an interesting lecture on the Era of Farm Machinery. On Thursday evening the attendance at the reception in the magnificent ball room of the Hotel Astor was nearly 600.

OPENING SESSION, TUESDAY EVENING

The President's reception on Tuesday evening was undoubtedly one of the most enjoyable ever held, the members and guests comfortably filling the handsomely decorated rooms of the Society, though the inclement weather doubtless prevented a larger attendance.

The session was called to order in the auditorium by Vice-President Fred J. Miller, who presented President Jesse M. Smith. President Smith then proceeded with his address on The Profession of Engineering, which is printed in full in this number. It deals mainly with the need of coöperation among engineers, looking toward the maintenance of high standards in engineering practice.

Following the address, Theodore Stebbins, chairman of the Tellers of Election, presented to the President the report on the election of officers and the following were thereupon declared elected: For president, George Westinghouse; for vice-presidents, Charles Whiting

Baker, W. F. M. Goss, E. D. Meier; for managers, J. Sellers Bancroft, James Hartness, H. G. Reist; for treasurer, William H. Wiley.

President Smith then called on Past-Presidents Worcester R. Warner, Geo. W. Melville and Samuel T. Wellman to escort President-elect George Westinghouse to the platform.

After his notification of election and introduction to the members, the president-elect spoke as follows:

When Mr. Warner, the Chairman of your Nominating Committee, after first writing on the subject, came to Lenox to ask me to accept the nomination for president of this great Society, I had already decided that it would be impossible for me to have the privilege of accepting; but after he had explained to me the desires of his associates and had represented to me that it was the unanimous wish of all of the members of your Nominating Committee to honor me at this particular time, and in so doing to express an appreciation of my efforts and accomplishments in the engineering field, I with much hesitation consented to accept the nomination and promised if elected to do everything in my power.

Whether two mistakes have been made—one in yielding to the persuasive words of Mr. Warner, and the other in my election as your president—the forthcoming year will determine. I trust I may be able to fulfil your expectations by adding something to the worldwide reputation of The American Society of Mechanical Engineers.

With these remarks, I now accept with feelings of deep gratitude the honor which the members of the Society have tonight unanimously conferred upon me.

There never was a time in the history of the world when honest, wise and conservative action is more strongly demanded of us and of all men than now, if we have any desire to preserve the right to comfortably carry on our various affairs.

I thank you, and I ask your coöperation in my efforts to perform my duties as your president.

The meeting was then adjourned to the rooms of the Society where the members and guests were introduced by Secretary Calvin W. Rice, to the President-elect and Mrs. Westinghouse, those also in the receiving line being President Jesse M. Smith and Mrs. Smith, Mrs. Hutton and Honorary Secretary F. R. Hutton.

WEDNESDAY EVENING LECTURE

As already stated the lecture on Wednesday evening was on the Era of Farm Machinery, by L. W. Ellis, of the Bureau of Plant Industry of the United States Department of Agriculture at Washington, D. C. The lecture was illustrated by lantern slides. Mr. Ellis first gave an idea of agricultural progress, by describing some of the most striking mechanical achievements found on Western farms of the present day. He first described early farm implements and told briefly of the

transition from hand to machine methods. In 1800 wheat was sown broadcast by hand, after the ground had been plowed with a heavy, clumsy, wooden plow, requiring as many as eight oxen to pull it. Sickles cut the grain, and it was bound by hand. During the succeeding winter it was threshed out either by a flail or by driving animals over it as it lay in heaps. It was finally winnowed by hand.

Corn cultivation was by the hoe, or a rude shovel plow. The stalks were cut and the ears husked out by hand. Shelling was done by scraping the ears against the handle of a frying pan—a bushel in one hundred minutes.

Hay was cut with a scythe and was pitched by hand from ground to cart, and cart to haymow. Baling and shipping were practically unknown. Hand methods prevailed in the dairy, the stable, the cotton fields, the potato patch—in fact in every phase of production.

From 1855 to 1894 the human labor consumed in producing a bushel of corn by the best available methods declined from four hours and thirty minutes to forty-one minutes, and for shelling it from one hundred minutes to one minute. In 1830, three hours and three minutes of human labor were required to raise and thresh a bushel of wheat—in 1896 ten minutes. Eleven hours were required to cut and cure a ton of hay in 1860, and but one hour and thirty-nine minutes in 1894.

Power corn shellers now used have a capacity of from one hundred to eight hundred bushels per day. The cobs are carried to a pile and the shelled corn delivered into sacks or wagons. The fuel value of the cobs pays the cost of shelling.

Though hand methods still prevail in some sections, the mower is now practically the universal means of cutting the hay crop. This is a modification of the early reaping machines with such factors eliminated as are not necessary for cutting the grass. The steel self-dump rake, the side-delivery rake and the hay loader, the stacker, and the bailing press are other developments for hay harvesting.

In the extreme West there has been developed the combined harvester which seems to represent the greatest possible saving of human labor. This machine, drawn by from twenty to forty horses, under control of a single driver, cuts, threshes, recleans, and delivers into sacks the grain from forty to fifty acres per day. Two men are required for sewing the sacks. The straw, including all weed seeds, is distributed over the ground as the team proceeds. On level land the horses may be replaced by the steam engine, which furnishes power sufficient to cut a swath up to forty feet in width and to cover from seventy-five to one hundred and twenty-five acres per day.

For general farm work the internal-combustion tractor may be said to be rapidly supplanting the steam engine, which, however, has a great field of usefulness in sections where it is desired to bring large areas rapidly under cultivation. In older sections, in order to compete successfully with the horse, tractors must bring the cost of operation close to the cost with horses and at the same time be capable of a great variety of work. The internal-combustion tractor meets these conditions better than the steam engine, and is being introduced at a rate estimated anywhere from two thousand to five thousand per year.

The automobile is rapidly finding a place in the business management of the farm. It takes from the heavy draft horse the necessity for long, exhausting trips to town on light errands.

In general, machinery has reduced the cost of producing farm products. It has improved the quality of products by condensing crop operations within the period when the most favorable conditions prevail. By increasing the acre effectiveness of a man it has reduced the labor necessary to produce the nation's food supply, leaving it free to assist in development along other lines. At the same time it has thrown upon the cities the burden of providing work for an ever increasing army of non-producers. It has increased the investment necessary for the proper organization of a farm, this and the price of land making it more difficult for a person of small capital to engage in farming.

As a nation we have occupied nearly all of our naturally productive area and are confronted with the necessity of providing food for an increasing population with a constant acreage. In the past, machinery has encouraged extensive rather than intensive farming. Henceforth the reverse should be true. If he who makes two blades of grass grow where one grew before, is a public benefactor, then none the less is he a public servant who puts into the farmer's hands the machinery for making such a course attractive.

BUSINESS MEETING

The business session on Wednesday morning was called to order by President Jesse M. Smith. Secretary Calvin W. Rice read the annual report of the Council. The Secretary then read the report of the Tellers of Election of members, which will be published in the membership list of the Society. The list included 166 applicants for membership and 21 for advance in grade.

The next in order was the consideration of the proposed amendments to the Constitution. The first amendment relates to C 10 on associate membership, which reads as follows:

C 10 An Associate shall be 26 years of age or over. He must either have the other qualifications of a member or be so connected with engineering as to be competent to take charge of engineering work, or to coöperate with engineers.

The proposed amendment reads as follows:

An associate member shall be thirty years of age or over; he must have been so connected with some branch of engineering, or science, or the arts, or industries, that the Council will consider him qualified to coöperate with engineers in the advancement of professional knowledge.

Another amendment relates to the clause on Junior Membership which now reads as follows:

C 11 A Junior shall be 21 years of age or over. He must have had such engineering experience as will enable him to fill a responsible subordinate position in engineering work, or he must be a graduate of an engineering school.

The following addition is proposed by the Committee on Constitution and By-Laws:

A person who is over 30 years of age can not enter the Society as a Junior.

Both these amendments have been approved by the Committee on Membership. It therefore remains for the members to vote on them by letter ballot.

A third proposed amendment to the Constitution relates to the formation of an additional standing committee. This was presented at the Washington meeting in the form of a resolution, as follows:

Resolved, That we recommend to the Council the appointment of a Public Relations Committee, to investigate, consider and report on the methods whereby the Society may more directly coöperate with the public on engineering matters and on the general policy which should control such coöperation.

It was moved and seconded that this also be referred to the members for letter ballot.

Dr. D. S. Jacobus, Chairman of the Committee on Power Tests, then made a verbal report. This committee was appointed to revise all the codes relating to power tests, some of which did not agree with others, or were not up to date. It had been decided to blend the whole into one report rather than present a series of reports, as on engine testing, boiler testing, etc. The first part of the report will deal with tests in general, calibration of apparatus, units, etc., while

the second part will be subdivided for the various classes of machines and apparatus.

Geo. H. Barrus had volunteered to prepare a skeleton of the report and had done excellent work in this respect, the material making 69 closely type-written pages. Copies of this outline were in the hands of the members of the committee and would shortly be discussed by them.

Dr. Jacobus also made a verbal report for the Joint Committee on a Standard Tonnage Basis for Refrigeration. This committee had made a preliminary report in 1904 and suggested certain units for measuring the refrigerating capacity of the machinery. They had also suggested a standard set of conditions under which a machine should be tested to obtain the refrigerating capacity of that machine. Later on, the work of the committee was extended, and they were asked to recommend a method of testing the machines. A preliminary report was also prepared on this portion of the work and had been before the Society.

Though the committee had received some favorable discussion on the report they felt that it was not a complete piece of work, and they wished that some one would give the committee additional light on how the report could be made. Furthermore, there were many places in the report where the committee could not make any definite recommendations, because they did not have enough data at hand.

A résumé of the work that has been done by the Committee on Refrigeration was prepared and sent to the Congress of Refrigerating Industries, held in Paris in the fall of 1908, with the request that it be discussed. In making this résumé certain questions were asked, on which the committee wished to obtain specific information. This was done in a semi-official way, and after taking up the matter with the Secretary of this Society, the committee ended the communication to the International Committee in this way:

The policy of The American Society of Mechanical Engineers has always been for the advancement of the arts, and whereas it is only natural that it should take pride in participating in advancements, it will never look except with satisfaction upon activities of other bodies, even in the subjects on which it has worked.

I feel safe in saying, therefore, that any criticism by the members of this organization on the work which has been done in connection with the subject at hand will be gladly received. Criticism leads to the establishment of better and more up-to-date methods, and what The American Society of Mechanical Engineers is after, and what I am sure we are all after, is to work hand in hand for the good of the cause.

I also feel safe in saying that The American Society of Mechanical Engineers

will coöperate in every way in the endeavor to establish some standard set of rules which shall conform with the views of such able experts as are gathered in this meeting. It is certainly hoped that the matter presented in this paper will receive a thorough discussion, irrespective of whether those who take part agree or disagree with the findings of the committee.

About the same time, a request was made by the committee that it should be allowed to coöperate with a committee of the American Society of Refrigerating Engineers, so that if this general committee recommended certain units, they would really be used by both Societies. A committee of five was appointed by the American Society of Refrigerating Engineers to coöperate with the committee of five of The American Society of Mechanical Engineers. This combined committee has already held one meeting and sent out a circular letter to a number of refrigerating engineers, reviewing the units that had been recommended by the Society, and asking for an opinion regarding these specific units. A great number of replies had been received, showing how much interest there is in the subject. Most of the replies said either that the units were acceptable to those who had read the letter, or that they would leave the selection of the units entirely in the hands of the committee. The committee therefore has a very good working basis, and hopes within a comparatively short time to be able to present the results of its work.

Dr. C. E. Lucke then abstracted the report of the Gas Power Standardization Committee, of which he is chairman. The report was discussed by Dr. D. S. Jacobus, Prof. R. H. Fernald, A. A. Cary, Edwin D. Dreyfus and L. B. Lent.

The report of the Gas Power Plant Operations Committee was presented by F. R. Low in the absence of I. E. Moultrop, chairman of the committee. The report was discussed by Prof. R. H. Fernald, Edwin D. Dreyfus, and Arthur J. Wood.

THURSDAY MORNING SESSION

The Thursday morning session was devoted to papers on the measurement of the flow of fluids.

The first paper presented was on Tests on a Venturi Meter for Boiler Feed, by Prof. C. M. Allen, of Worcester Polytechnic Institute. The object of these tests with the venturi meter was to determine how well adapted it would be for use in measuring the feed to a boiler, in view of the variety of conditions under which it might have to operate. The methods of pumping the water through the meter, the different temperatures of the water pumped, various and fluctuating

pressures and velocities of flow, any one or several of these conditions might be met in actual service, and the results obtained indicate that such occurrence would have practically no effect on the satisfactory performance of the work of the meter. Though there are limits to the satisfactory operation of any one meter, the tests indicate that the venturi meter is sufficiently accurate for the majority of commercial or engineering requirements.

The paper was discussed by F. N. Connet and Clemens Herschel, Dr. Sanford A. Moss and Prof. L. S. Marks submitting written discussions.

The next paper, Efficiency Tests of Steam Nozzles, by Prof. F. H. Sibley, of the University of Alabama, was read by Prof. C. C. Thomas of the University of Wisconsin. The object of the test was to determine the efficiency of various shaped nozzles with steam flowing from a given initial pressure to a known vacuum; also to determine the effect on the efficiency of changing the angle of divergence. Two methods were tried out for finding this efficiency: (*a*) by first finding the pressure in the nozzle by means of a search tube placed axially in the nozzle; (*b*) by finding the reaction of the nozzle by suspending it in an air-tight box at the end of a flexible steel tube. The deflection of the tube caused by the reaction of the nozzle was measured by a calibrated spring. The results of the tests indicate: (*a*) that the reaction is affected by a difference in pressure between the muzzle of the nozzle and the medium surrounding the nozzle; (*b*) that the efficiencies of the various nozzles were determined within a probable error of 2 per cent; (*c*) that the efficiency is affected more by the smoothness of finish on the inside of the nozzle than by the exact contour of the nozzle.

A. F. Nagle, A. R. Dodge and Professor Thomas discussed the paper, J. A. Moyer submitting a written discussion.

George F. Gebhardt's paper on The Pitot Tube as a Steam Meter was read by the Secretary in the author's absence. The application of a pitot tube system as described in the paper is an accurate means of determining the *velocity* of steam at any point in a pipe, provided the values of the various influencing factors are known; and for straight lengths of piping with continuous flow, under these conditions, it is an accurate means of determining the *weight* of steam flowing. Under average commercial conditions in which the pressure and quality of the steam fluctuate and an average value must be taken for the density of the self-adjusting water column, only approximate results can be obtained, the extent varying with the degree of fluctuation.

Walter Ferris and A. R. Dodge discussed the paper, a written discussion by Prof. W. B. Gregory being read by the Secretary.

The paper on An Electric Gas Meter was presented by the author, Prof. Carl C. Thomas, of the University of Wisconsin. The paper describes a meter measuring the rate of flow of gas or air, which can be adapted for use as a steam meter or as a steam calorimeter. The operation of the gas meter depends upon the principle of adding electrically a known quantity of heat to the gas and determining the rate of flow by the rise in temperature of the gas (about 5 deg. fahr.) between inlet and outlet. The adoption of this principle of operation permits the construction of a very accurate and sensitive autographic meter of large capacity containing no moving parts in the gas passage; independent of fluctuations in pressure and temperature of the gas; and capable of measuring gas or air at either high or low pressures or temperatures. The electrical energy required is about 1 kw. per 50,000 cu. ft. hourly capacity, at the pressures ordinarily used in gas mains.

Prof. W. D. Ennis, E. D. Dreyfus and A. R. Dodge discussed the paper, a written discussion from Prof. L. S. Marks being read also.

THURSDAY AFTERNOON—STEAM ENGINEERING

At the Thursday afternoon session Vice-President L. P. Breckenridge presided. Five papers were presented dealing with different phases of steam engineering. The first paper, Tan Bark as a Boiler Fuel, by David M. Myers, described the results obtained by burning spent hemlock tan bark, the average fuel value of which is about 9500 B.t.u. per lb. of dry matter, which is about 35 per cent of its total moist weight in the fireroom. The available heat value per pound as fired is 2665 B.t.u. One ton of air-dry hemlock bark produces boiler fuel equal to 0.42 tons of 13,500 B.t.u. coal. A. A. Cary, Prof. Wm. Kent and Prof. L. P. Breckenridge took part in the discussion.

J. R. Bibbins then presented his paper on Cooling Towers for Steam and Gas-Power Plants, which contained a critical study of different types of towers with a description of their distinctive features. The paper also describes a simple inexpensive type of tower employing a lath-mat cooling surface and offers suggestions for a combination of natural-draft and forced-draft types.

The paper was discussed by Geo. J. Foran, W. D. Ennis, H. E. Longwell, B. H. Coffey, E. D. Dreyfus and F. J. Bryant. A written discussion by Carl G. de Laval was read by the Secretary.

W. P. Caine's paper, Governing Rolling Mill Engines, was read by Richard H. Rice. The paper describes and gives indicator cards and speed curves of a Corliss engine driving a three-high mill under two different conditions of governing, (*a*) under the widest range of adjustment of cut-off, (*b*) under a limited range, increasing the economy and making the engine run much more smoothly and safely. A table gives the power required for rolling in the mill and the momentary source of energy, whether from the cylinder or flywheel. A description is also given of the tachometer used to take the speed curves. Written discussions by H. C. Ord and James Tribe were read by the Secretary.

The next paper was that by F. W. Dean on An Experience with Leaky Vertical Fire-Tube Boilers. The author discussed the difficulties experienced with some large vertical boilers, somewhat over 10 ft. in diameter, and containing over 6000 sq. ft. of heating surface The boilers leaked badly very soon after being started and nothing that was done improved their condition until the water legs were lengthened from 2 ft. to 7 ft. 2¾ in., the boilers thus being raised 5 ft. 2¾ in. Before they were raised the lower ends of the tubes would cover with very hard clinker and become stopped up. This clinker could be removed only by cutting it off when the boilers were cold. After the boilers were raised, a light clinker that could be blown off formed about the tubes; by removing this by blowing every three or four hours the leaks were stopped and they have never returned.

Those taking part in the discussion were R. P. Bolton, Prof. Wm. Kent, J. C. Parker, O. C. Woolson, A. A. Cary, Prof. A. M. Greene, Jr., E. D. Meier and D. M. Myers. A. Bement submitted a written discussion.

Mr. Dean's second paper, The Best Form of Longitudinal Joint for Boilers, dealt with the defects of the usual form of butt joint used on the longitudinal seams of boilers, in which the inside strap is wider than the outside strap. It gave some history of the joint and discussed some of its defects and suggested a substitution for this form.

The paper was discussed by R. P. Bolton, Carl G. Barth, E. D. Meier, Prof. A. M. Greene, Jr., W. A. Jones, Prof. S. W. Robinson, Geo. I. Rockwood, and Sherwood F. Jeter.

GAS POWER SECTION

The session of the Gas Power Section was held on Thursday afternoon, Chairman F. R. Low presiding. In his address, the Chairman

referred briefly to the work of the various committees of the Section and stated that during the year the membership had increased from 247 to 378, a gain of over 50 per cent. Mr. Low also dealt with the development in the gas-power field during the year, mentioning some experiments with gas turbines. Gas-engine design, the use of by-product gases, the development of the bituminous producer, the gasification of peat, and the gas engine in marine work, were also briefly dealt with.

The report of the Tellers of Election, Edw. Van Winkle, Prof. Walter Rautenstrauch and J. V. V. Colwell, was then presented by Prof. Rautenstrauch, the results being as follows: for chairman J. R. Bibbins 107; for member of the Executive Committee, F. R. Low 108.

The report of the Gas Power Plant Operations Committee was then presented by James D. Andrew, and discussed by J. C. Parker, J. N. Norris and H. H. Suplee. Prof. C. H. Benjamin reported verbally for the Literature Committee, outlining the work of the committee in bringing gas-power literature to the attention of the members. H. R. Cobleigh and Professor Rautenstrauch also spoke on the work of this committee, the latter suggesting a plan for better organization of the committee to deal with literature on the subject.

L. B. Lent reported for the Gas Power Installations Committee that two forms had been prepared and sent to manufacturers, and while a good deal of information had been received, not enough was on hand for a complete report. The committee hoped to have the material in shape at an early date.

Prof. W. F. M. Goss then presented the paper on Testing Suction Gas Producers with a Koerting Ejector, by C. M. Garland and A. P. Kratz. The paper describes a method of testing the suction gas producer which is independent of the engine. The engine is blanked off from the producer and a Schutte & Koerting steam ejector is inserted, which draws the gases from the producer and delivers them to a scrubber in which the steam used by the ejector is condensed. The gases then pass to a meter for measuring their volume. Complete data of calculations and results are given in appendices.

The paper was discussed by Prof. R. H. Fernald, G. M. Tait, H. H. Suplee, L. B. Lent, S. C. Smith, W. B. Chapman and Edw. N. Trump.

The paper on Bituminous Gas Producers was then presented by the author, J. R. Bibbins. The paper describes a double-zone type of producer and the results obtained in gasifying bituminous coal. Continuous operation was secured with tar-free gas of reasonable heat value and producer efficiency and an over-all plant economy of about

one pound of fair bituminous coal per brake horsepower (proportionate economies for poorer grades). The efficiency and general effectiveness of operation of the producer on low-grade fuel, lignites, etc., was practically as high as with the higher grades. The following took part in the discussion: G. M. Tait, Prof. R. H. Fernald, W. B. Chapman, H. M. Latham, H. H. Suplee, Edw. N. Trump, H. B. Langer, S. C. Smith, Prof. W. Rautenstrauch, and G. D. Conlee.

FRIDAY MORNING

The session on Friday morning opened with the paper by Walter Ferris on The Bucyrus Locomotive Pile Driver. This paper describes a new railway pile driver, the leading feature of which is a very powerful propelling apparatus and a large boiler, enabling it to act as a locomotive and haul its own train of tool cars, boarding cars, etc., over the road. A special turn-table, consisting of hydraulic lifting apparatus and a large ball-bearing, enables the entire pile driver, including trucks, to be turned end for end or crosswise of the tracks. O. K. Harlan discussed the paper, A. F. Robinson and L. J. Hotchkiss submitting written discussions.

The paper by Henry Hess on Lineshaft Efficiency, Mechanical and Economic, described the test of the relative efficiency of a lineshaft of $2\frac{7}{16}$ in. diameter, making 214 r.p.m., with bearing load due to the weight of the parts plus the tension of the belts subjected to known stress by counterweighting, when running in ring-oiling babbitted bearings and when mounted in ball bearings. The savings in power consequent on this change ranged from 14 to 65 per cent, with 36 and 35 per cent under average conditions of good practice, due to belt tensions of 44 lb. and 57 lb. per inch width of single belt respectively. The paper gives data for determining the power savings that may be expected in various plants, by the use of ball bearings.

Those discussing the paper were T. F. Salter, Prof. R. C. Carpenter, C. A. Graves, O. K. Harlan, C. J. H. Woodbury, Walter Ferris, Fred J. Miller, A. C. Jackson, C. D. Parker and Oliver B. Zimmerman. Geo. N. Van Derhoff submitted a written discussion.

A. F. Nagle's paper on Pump Valves and Valve Areas, called the attention of engineers to the need of reviewing the common notion that "valve-seat area" is synonymous with "velocity of flow." The purpose of specifications for pumping engines is to secure a low velocity of flow through the valves, thus reducing the head required to force water through the pump; but to accomplish this purpose, special

and intelligent attention should be given to the springs of the valves, rather than to valve-seat areas. If that be done, valve-seat areas need not be greater than the plunger area for the vertical triple-expansion pumping engines so largely used in city pumps. Prof. W. M. Kent, A. B. Carhart, Prof. R. C. Carpenter and E. H. Foster discussed the paper. Contributed discussions were by Chas. A. Hague, I. H. Reynolds and F. W. Salmon.

Another paper by Mr. Nagle, a Report on Cast-Iron Test Bars, brought out the fact that test pieces, whether cast in separate molds or in the same mold as the main casting, are not perfect indications of the character of the iron in the main casting. The results obtained by the author would indicate a probable variation of 15 per cent where uniformity might be expected. A. A. Cary and T. M. Phetteplace discussed the paper, contributed discussion being by Prof. W. B. Gregory and Geo. M. Peek.

The meeting closed with the following resolutions, offered by Luther D. Burlingame:

Whereas The American Society of Mechanical Engineers at its Annual Meeting, December 1909, desires to express its appreciation to those who have provided opportunities for entertainment and on behalf of the visiting members and their guests thanks for the cordial welcome extended by the local members and their friends of New York and vicinity,

Be it Resolved that the Secretary extend the thanks of the Society and express the appreciation of its members and guests to the local committee for their untiring efforts, to those who have sent invitations to visit technical and engineering works and places of interest, to Mr. Geo. Gibbs, chief engineer of the Pennsylvania Tunnel and Terminal Railroad Co., and to Mr. Walter Kerr, president of the Westinghouse, Church, Kerr & Co., and their associates, for the opportunity to inspect the new Pennsylvania Railroad station; to Dr. B. T. Galloway, chief of the Bureau of Plant Industry, Department of Agriculture, for the very instructive and entertaining paper on The Era of Agricultural Machinery, and especially to those ladies who have so efficiently assisted by extending a generous hospitality to their guests.

EXCURSIONS

As usual at Conventions of the Society there were numerous excursions to points of interest in New York and vicinity, which constituted an important feature of the program for the entertainment

of visiting members and guests. Invitations for these excursions were generously extended by many firms and individuals, and through the efforts of the Excursion Committee, Hosea Webster, *Chairman*, trips to various plants and industries were arranged, to the representatives of which the grateful appreciation of the Society has been expressed.

A list of excursions follows:

Pennsylvania Railroad Terminal and Passenger Station: Invitation by George Gibbs, Chief Engineer, Pennsylvania Tunnel Terminal R. R. Co., and member of the Society; Henry R. Worthington Hydraulic Works, Harrison, N. J., by William Schwanhausser, Chief Consulting Engineer of International Steam Pump Co., member of the Society; Harrison Lamp Works of General Electric Co., Harrison, N. J., by George H. Morrison, General Manager; Interborough Rapid Transit Co., central power station at 59th St., New York, by H. G. Stott, Superintendent of Motive Power, Manager of the Society; Edison factories and Edison Laboratory at Orange, N. J., by Frank L. Dyer, President of National Phonograph Co., associate member of the Society; De La Vergne Machine Co., New York, by Adolf Bender, President; New York Telephone Co.; Gramercy and Stuyvesant Central Offices, by E. F. Sherwood, Superintendent of Traffic; Crocker-Wheeler Co., Ampere, N. J., by S. S. Wheeler, President, member of the Society; Westinghouse Lamp Co., Bloomfield, N. J., by Walter Carey, General Manager; New York Edison Co., Waterside Stations Nos. 1 and 2, by John W. Lieb, Jr., 3d Vice-President, member of the Society; Astoria Light, Heat & Power Co., Astoria, N. Y., by William H. Bradley, Chief Engineer, Consolidated Gas Co., member of the Society; Brooklyn Rapid Transit Co., Williamsburg Power Station, by C. E. Roehl, Electrical Engineer; Rockland Electric Co., Hillburn, N. Y.; Singer Building, New York, by Singer Mfg. Co.; Trenton Iron Co., Trenton, N. J.; Watson-Stillman Co., Ampere, N. J.; Metropolitan Life Insurance Building, New York.

Every possible courtesy was extended to the visiting parties in each case and in some instances special transportation facilities were provided. At the Edison Laboratory visitors were met by Thomas A. Edison, Hon.Mem.Am.Soc.M.E., who personally explained many points of interest about the plant. In order to avoid confusion, arrangements were made to assemble at the various manufactories at a time and place indicated in the program. The Information Bureau, located in the foyer of the building, under the chairmanship of F. E. Idell, was of material aid in this connection.

ENTERTAINMENT FEATURES

The Ladies' Reception Committee, composed of ladies resident in and about New York, under the chairmanship of Mrs. Herbert Gray Torrey, contributed much to the pleasure of members and guests of the Society. Tea was served from four until six o'clock on Tues-

day, Wednesday, and Thursday afternoons during the convention, in the ladies' headquarters in the reception rooms of the Society on the eleventh floor. Mrs. George H. Westinghouse was the guest of the committee on Wednesday afternoon.

A number of excursions to shops and hotels were arranged and successfully carried out under the guidance of members of the committee. The kindness of Mr. and Mrs. John W. Lieb, Jr., made possible several enjoyable automobile rides through Central Park and Riverside Drive.

MEETINGS OF THE COUNCIL

DECEMBER 7, 1909

A meeting of the Council was called to order December 7, 1909, in the rooms of the Society, with President Smith in the chair. There were present at the meeting Geo. M. Basford, Geo. M. Bond, L. P. Breckenridge, R. C. Carpenter, H. L. Gantt, A. C. Humphreys, F. J. Miller, A. M. Waitt, Past-Presidents Charles Wallace Hunt, F. R. Hutton, Ambrose Swasey, F. W. Taylor and S. T. Wellman, and Calvin W. Rice, Secretary. The Council was especially pleased to have present John Fritz, Honorary Member and Past-President.

The minutes of the previous meeting were read and approved. The Secretary reported the deaths of Charles H. Willcox and William Metcalf.

The amendments to By-Laws B-6, B-7, B-12, B-13, B-18, B-19, B-27, B-28, B-34, and B-36 and the new By-Laws, one providing for the appointment of a Trustee of the United Engineering Society and one respecting The Journal of the Society, were approved.

EXECUTIVE COMMITTEE

Voted: That the Council sees no objection to any group of members selecting their own fiscal agent or correspondent, through whom the transmittal of their dues and other indebtedness to the Society may be made.

Voted: To refer the communication of the Western Society of Engineers, regarding the revision of the building laws of the State of Illinois, to the Public Relations Committee, to be appointed.

Voted: To approve the exchange of house and library privileges with the Louisiana Engineering Society.

The Secretary reported that circulars regarding the Joint Meeting in England had been issued to the membership and 116 favorable replies had already been received.

Voted: That the Council approve the recommendation of the Executive Committee approving coöperation with the Association of

American Steel Manufacturers to secure the general adoption of a system approved by a committee of the Society, December, 1894 (Trans., vol. 16, p. 32), to call the thickness of metals by their dimensions in decimals of an inch rather than by arbitrary number, and the Council recommends that the President appoint a committee to cöoperate with the Association.

The following were constituted such a committee: S. T. Wellman and George M. Bond.

The resolution referred to the Council from the Washington meeting, regarding the increase of facilities of the United States Patent Office, was laid on the table.

FINANCE COMMITTEE

The following resolutions were received from the Finance Committee and on motion approved:

That the Finance Committee recommend to the Council that the transfer of 10 per cent of the Reserve Fund of the Current Income Account be discontinued, as rceommended in the Annual Report.

That the Secretary be authorized to charge against this Annual Meeting Sub scription Fund, namely, $205.60, whatever bills may have been incurred by the office in behalf of the Local Committee for the Annual Meeting, and the balance, if any, be paid by the Treasurer to the Local Committee of 1909.

Voted: To approve the recommendation of the Finance Committee that a committee be appointed to take up the consideration of the question of increasing the membership and providing ways and means to put the same into effect during the coming year.

LIBRARY COMMITTEE

Voted: To adopt the following resolutions of the Library Committee but with the amendment that the House Committee have the first option on duplicate books, to enable that Committee to furnish the reception room:

To recommend to the Council that the Librarian be authorized to sell to the highest bidder, for the benefit of the Society, the duplicate books recommended in the letter of the Librarian to the Committee, dated July 23, 1909.

MEETINGS COMMITTEE

Voted: To receive the resolution of the Meetings Committee, to whom had been referred the action of the Council on a Machine Shop Section, but to amend to read:

> *Voted:* To advise the Council that the Committee is in accord with the plans of the Council for carrying out the purpose of a Machine Shop Section through committees appointed by the Meetings Committee and not by the formation of a special section; and that the Committee will proceed to such plans as soon as possible.

Voted: To approve the recommendation of Atlantic City for the Spring Meeting of the Society, May 31 to June 3, 1910.

STUDENT BRANCHES

Voted: On recommendation of Professor Hutton, Chairman of the Sub-Committee on Student Branches, to approve the applications of the University of Nebraska at Lincoln, Neb., and the University of Missouri at Columbus, Mo., to form student branches of the Society.

A communication was read by the Secretary regarding the possibility of holding meetings of the Society in Chicago, along the lines of those in St. Louis and Boston.

The Secretary presented a draft of the annual report of the Council which after amendment, was approved and ordered filed and printed as the report of the Council for 1909.

Voted: That the Library Committee be requested to give consideration to the question of procuring and caring for a collection of lantern slides.

THURSTON MEMORIAL

Dr. Humphreys reported the intention of the Thurston Memorial Committee to have the dedication exercises in February at the regular monthly meeting of the Society, and requested suggestions from the Council of suitable speakers for that evening, covering the various phases of Dr. Thurston's life work at the Naval Academy, Stevens Institute and Cornell University, as well as his laboratory and research work and work in connection with the organization of the Society.

The meeting adjourned.

DECEMBER 10, 1909

A meeting of the Council was called to order by Jesse M. Smith, Past-President, on December 10, 1909, in the rooms of the Society.

Mr. Smith appointed Vice-President R. C. Carpenter and Manager I. E. Moultrop a committee to introduce to the Council the Vice-Presidents-elect and Managers-elect, and Past-Presidents Taylor and Hutton to introduce the President-elect, George Westinghouse.

Mr. Westinghouse then took the chair.

There were present at the meeting: President, George Westinghouse; Vice-Presidents, Chas. Whiting Baker, Geo. M. Bond, R. C. Carpenter, W. F. M. Goss, E. D. Meier, F. M. Whyte; Managers, J. Sellers Bancroft, H. L. Gantt, James Hartness, Alex. C. Humphreys, I. E. Moultrop, H. G. Reist, H. G. Stott; Past-Presidents, F. R. Hutton, Charles Wallace Hunt, Jesse M. Smith; Chairman Finance Committee, Arthur M. Waitt, and Secretary, Calvin W. Rice. Regrets were received from Treasurer, Wm. H. Wiley, and Manager, W. J. Sando.

The minutes of the meeting of December 7 were read and approved.

In the absence from the room of Calvin W. Rice, Secretary of the Society for the year 1909, H. G. Stott acted as Secretary *pro tem.*

Voted: That Calvin W. Rice be elected Secretary for the year 1910 on the same terms as the previous year.

Voted: That F. R. Hutton be elected Honorary Secretary for the year 1910, on the same terms as the previous year.

Voted: That Jesse M. Smith, Past-President, be elected Trustee of the United Engineering Society to serve for a term of three years, to fill the vacancy created by the expiration of the term of office of Charles Wallace Hunt.

Voted: That Henry R. Towne be reappointed a member of the John Fritz Medal Committee, under the provisions of C-46 and B-32 to serve for a term of four years, to succeed himself.

Voted: That the Council delegate to the President the appointment of the Executive Committee of the Council for the year 1910 and until the appointment of the new Executive Committee the present Executive Committee continue in service.

The meeting adjourned to January 11, 1910.

THE NEWLY ELECTED OFFICERS FOR 1910

GEORGE WESTINGHOUSE

President Am. Soc. M. E.

George Westinghouse, a son of George and Emeline Vedder Westinghouse, was born at Central Bridge, N. Y., October 6, 1846. His father was a manufacturer of agricultural machinery, and established works at Schenectady, which are still in operation. The younger Westinghouse was educated in the public schools and at Union College, Schenectady, and received his early mechanical training in his father's manufactory. His tastes were strongly in the direction of machinery and the solution of mechanical problems.

The patriotic ardor which filled the youth of the country during the civil war drew young Westinghouse into the volunteer army in June 1863. He was under seventeen, but on account of his size and strength—he was six feet tall and weighed 180 lb.—the recruiting officers admitted him without asking his age. He enlisted with the Twelfth New York National Guard. Subsequently, he joined the Sixteenth New York Cavalry, and in December 1864 became an assistant engineer in the United States Navy, serving in that capacity until August 1865.

Returning to civil life he invented in the same year a device for replacing derailed cars, and while placing this invention with the railroads his attention was attracted by the prevalence of minor and serious accidents due to the lack of efficient means for controlling trains in motion. After a careful study of the subject, and such experiments as were possible with the limited means then obtainable, he invented the air brake and patented it in 1868.

The first train to which this brake was applied ran on a line west from Pittsburgh and on what is now a portion of the Pennsylvania Railroad. During the trial trip a collision with a loaded team stuck on a grade-crossing was prevented. This practical illustration of the utility of the invention led to the adoption of the brake. Mr. Westinghouse, retaining the control of his invention, undertook to manufacture it and organized the Westinghouse Air Brake Company,

establishing at Pittsburgh the business which subsequently became the nucleus of the many industries associated with his name.

From the invention of the air brake dates the beginning of modern railroading. The air brake is primarily a train-operating device which makes possible the fast and long trains, large cars, heavy loads and frequency of service of the present day, and the numerous improvements which Mr. Westinghouse has wrought in his invention have kept its efficiency well in advance of the new and varied conditions which constantly arise. Before he was twenty-five his name had become familiar throughout the world, and his contribution to the material progress of civilization was everywhere recognized. He continued in the study and practice of engineering, and equipped a machine shop for his personal experimental use, where he worked out many inventions, at first relating almost entirely to devices for railroad operations. He applied compressed air to switching and signalling and later utilized electricity in this connection. From this grew the Union Switch and Signal Co.

His introduction of electricity into switch and signal work led him far into electrical experiment and he devoted his energies to a cause in which few then believed, the adoption of the alternating current for lighting and power, in which he had to meet and overcome almost fanatical opposition, which in many States sought legislation against the use of the alternating current as dangerous to the public welfare. In 1885 he acquired the patents of Gaulard & Gibbs, and having undertaken a comprehensive study of the distribution and utilization of electrical currents in a large way, he personally devised apparatus and methods for the work, and gathered around him a group of men who were to become experts in the new electrical art. He also organized the electrical company which bears his name and undertook the development and manufacture of the induction motor which made practical the utilization of the alternating current for power purposes.

Following the discovery of natural gas in the Pittsburgh region, Mr. Westinghouse devised a system for controlling the flow and for conveying the gas over long distances through pipe lines, thus supplying fuel to the homes and factories of Pittsburgh. He took up the study of the gas engine, and for ten years conducted a series of exhaustive experiments in this line, at the end of that time putting into commercial use a gas engine of large power for electric generating.

Mr. Westinghouse introduced the Parsons steam-turbine into this country, adding to it improvements and developments of his own,

and others carried out under his supervision. He also has recently developed a steam turbine for ship-propulsion designed to overcome the well-known objections to the use of turbines in that field, and lately coöperated with Rear-Admiral Melville and John H. Macalpine in their study of problems associated with driving of propellers at low speed by turbines of high speed.

It is impracticable to enumerate here the inventions which Mr. Westinghouse has personally made or those which his staff have brought forth under his supervision. As a result of this work and enterprise, there have grown thirty corporations of which he is president, employing 50,000 men, $120,000,000 of capital, with works at Wilmerding, East Pittsburgh, Swissvale and Trafford City, Pa.; at Hamilton, Canada; London and Manchester, England; Havre, France Vardo, Italy; and at Vienna and St. Petersburg.

Mr. Westinghouse has made many visits to Europe in connection with his inventions and industries. There as in his own country he has won the friendship of the foremost men of his time and the high esteem of the engineering profession. He has been decorated by the French Republic and by the sovereigns of Italy and Belgium; and he was the second recipient of the John Fritz Medal, Lord Kelvin, his friend of many years, having been the first. The Königliche Technische Hochschule of Berlin bestowed upon him the degree of Doctor of Engineering; and his own college, Union, gave him the degree of Ph.D. In 1905 Mr. Westinghouse was selected as one of the three trustees in whose hands the voting power of the controlling stock interest in the Equitable Life Insurance Society was placed. The other trustees were Ex-President Grover Cleveland, and Justice Morgan J. O'Brien. The selection of these three men met with universal approbation. Besides his Honorary membership in The American Society of Mechanical Engineers, Mr. Westinghouse is one of the two honorary members of the American Association for the Advancement of Science and is an honorary member of the National Electric Light Association.

Mr. Westinghouse married, in 1867, Miss Marguerite Erskine Walker and has one son, George Westinghouse, Jr. While he claims Pittsburgh as his residence, he has also a country home at Erskine Park, Lenox, Mass., as well as a house in Washington.

VICE-PRESIDENTS

CHARLES WHITING BAKER

Charles Whiting Baker, editor and vice-president of Engineering News, was born in Johnson, Vt., January 17, 1865, and was educated at the State Normal School at Johnson and at the University of Vermont. He received the degree of Civil Engineer from the latter institution in 1886. During his course Mr. Baker spent one vacation as aid on triangulation work for the United States Coast and Geodetic Survey in Vermont, and on graduation he worked for a few months in the drafting room of the Baldwin Locomotive Works, at Philadelphia, Pa.

Leaving this position in February 1889 to become associate editor of Engineering News, of New York, Mr. Baker took up a work which has claimed his attention ever since. Since 1892 he has been in practical charge of the editorial department, becoming in 1895, on the death of A. M. Wellington, managing editor and secretary of the company. Ten years later he became vice-president.

Mr. Baker published in 1889 an economic work, Monopolies and the People, and he has contributed to the Society a paper entitled, What is the Heating Surface of a Steam Boiler, presented in June 1898. He joined the Society in 1893, and served on the Meetings Committee from 1905 to 1908.

WILLIAM FREEMAN MYRICK GOSS

William Freeman Myrick Goss was born in Barnstable, Mass., October 7, 1859. In 1879 he received the certificate of the Massachusetts Institute of Technology, and afterwards the degree of Hon. M.S., from Wabash in 1888, and D.Eng., from the University of Illinois in 1904.

In 1879 Dr. Goss became an instructor in the department of mechanic arts of Purdue University, and remained in the service of that institution for nearly thirty years, becoming successively professor of practical mechanics in 1883 and professor of experimental engineering in 1889. He was made a director of the engineering laboratory in 1899, and dean of the school of engineering in 1900. In 1907 Dr. Goss entered the University of Illinois as dean of the college of engineering and director of the school of railway engineering and administration.

Dr. Goss served on the jury of awards for the Columbian Exposition in 1893, and has been a member since 1906 of the executive committee of the National Advisory Board on Fuels and Structural Materials. He is a fellow of the American Association for the Advancement of Science, and a member of the Society for the Promotion of Engineering Education, the Western Railway Club, the Western Society of Engineers, the American Institute of Electrical Engineers, the Illinois Academy of Science, the Master Car Builders' Association, the Master Mechanics' Association, the International Association for Testing Materials, and the Illinois Society of Engineers and Surveyors.

Dr. Goss has made a specialty of the subject of steam engineering, investigating largely the economic performance of locomotives, high pressure in locomotive service, superheated steam in locomotive service, behavior of car axles, friction brakes, front-end arrangement of locomotives, fuel briquets in locomotive service, power transmission by friction wheels, graphite as a lubricant, etc.

Dr. Goss is a life member of this Society, which he entered in 1886. He was a member of the board of managers from 1900 to 1903, and has served on many committees. He has contributed the following papers: The Cole Locomotive Superheater; A Series Distilling Apparatus of High Efficiency; The Effect of the Counterbalance in Locomotive Drive Wheels upon the Pressure between Wheel and Rail; Tests of a Ten-Horsepower DeLaval Steam Turbine; New Forms of Friction Brakes; Tests of the Locomotive at the Laboratory of Purdue University; Paper Friction Wheels; Tests of a Twelve-Horsepower Gas Engine; Efficiency Tests of a One Hundred Twenty-Five Horsepower Gas Engine; The Effect upon the Diagrams, of Long Pipe Connections for Steam-Engine Indicators; Test of the Snow Pumping Engine at the Riverside Station of the Indianapolis Water Company; Locomotive Testing Plants; Power Transmission by Friction Driving; The Conservation of the Nation's Fuel Supply; The Debt of Modern Civilization to the Steam Engine.

EDWARD DANIEL MEIER

Colonel Edward Daniel Meier, president and chief engineer of the Heine Safety Boiler Conpamy, was born in St. Louis, Mo., May 30, 1841. At the close of a scientific course at Washington University, St. Louis, he studied four years at the Royal Polytechnic College at Hanover, from 1859 to 1862. He was then apprenticed to Wm. Mason's

Locomotive Works at Taunton, N. J. He left this company for military service, part of the time doing construction work as assistant engineer on the defenses of New Orleans.

In 1865 Colonel Meier entered the Rogers Locomotive Works at Paterson, N. J., as machinist and draftsman, During the next ten years he held various important positions with the Kansas Pacific Railway, the Illinois Patent Coke Company, the Meier Iron Company, the St. Louis Interstate Fair, and the St. Louis Cotton Factory. From 1876 to 1879 he was designer and superintendent of the Peper Hydraulic Cotton Press, and after two years of varied administrative work became president and chief engineer of the Heine Safety Boiler Company, which offices he still holds. During that period he has acted as consulting engineer on the Union Depot Railway of St. Louis, constructing the first electric power station in that city; and from 1902 to 1908 as engineer-in-chief and treasurer of the American Diesel Engine Company.

Colonel Meier has held office in the St. Louis Engineers' Club, the American Boiler Manufacturers' Association, and the Machinery and Metal Trades Association. He entered this Society in 1891 and has served it as manager, from 1895 to 1898, and as vice-president from 1898 to 1900.

MANAGERS

J. SELLERS BANCROFT

Mr. J. Sellers Bancroft was born September 12, 1843, and was educated in the public schools of Philadelphia.

In March 1861 he was apprenticed to the machinery business with Wm. Sellers & Co., with whom he was advanced to gang foreman in 1863, before the completion of his apprenticeship, and shop foreman in 1867, becoming a member of the firm in 1873, and manager of the business from its incorporation in 1887 to January 31, 1902, when he left this company to become general manager and mechanical engineer for the Lanston Monotype Machine Company, builders of monotype-casting and composing machinery. Mr. Bancroft has taken out over sixty patents for various inventions in machine tools, injectors, testing machines, electrical appliances, and type-casting and composing machines, and is largely responsible for the present condition of monotype machinery. He received a gold medal from the Paris Exposition of 1889 for his inventions in machine tools and injectors there shown.

Mr. Bancroft is a member of the American Association for the Advancement of Science, and has been a member of the Franklin Institute for over forty years. He entered this Society in 1880.

JAMES HARTNESS

James Hartness was born in Schenectady, N. Y., September 3, 1861, and received his early training in the public schools. After seven years of experience as machinist, toolmaker and draftsman, he became foreman and designer for the Union Hardware Company, of Torrington, Conn., a position which he relinquished after three years to become superintendent and designer for the Jones & Lamson Machine Co., of Springfield, Vt. He has had an active part in the management of this firm for nearly twenty-one years, and has been its president for the last nine years. Mr. Hartness is also president of the Bryant Chucking Grinder Company, treasurer of the Jones & Lamson Power Co., and director in a number of other machine tool building companies.

He has taken out seventy United States patents, besides many pending, his line of invention being machines for metal turning, notably the flat turret lathe.

Mr. Hartness published in 1909 a work on Machine Building for Profit and the Flat Turret Lathe, and has contributed to the Society, papers on Lead-Controlling Screw-Cutting Dies, and Tandem Dies, in 1897, and Metal-Cutting Tools without Clearance, in 1908. He joined the Society in 1891 and is a life member. He is also a member of the Institution of Mechanical Engineers of Great Britain, the American Society for the Advancement of Science, the American Institute for Scientific Research, and the Boston Chamber of Commerce, as well as the Engineers' Club, and various other social organizations.

HENRY G. REIST

Henry G. Reist was born near Mt. Joy, Lancaster County, Pa., May 27, 1862. He received from Lehigh University in 1886 the degree of M.E. The same year he entered the foundry and machine department of the Harrisburg Car Company. After a year of testing and erecting steam engines he became assistant superintendent of the company.

Leaving in the spring of 1889 to join the engineering excursion to Europe, he became associated on his return with the Thomson-

Houston Electric Company, at Lynn, Mass., having charge of the construction and testing of a large number of direct and alternating-current dynamos and stationary and railway motors. Soon after the consolidation of the Thomson-Houston Company with the General Electric Company, he took charge for them of the design of alternating-current generators and motors. When he was first engaged in electrical work, the largest machine manufactured by the company with which he was associated, was of 100-kw. capacity; now 14,000-kw. generators are regularly produced by this company.

Mr. Reist entered this Society in 1889 and somewhat later became a member of the American Institute of Electrical Engineers. He has contributed to the Society a paper on Blueprinting by Electric Light, and has presented papers before the American Institute of Electrical Engineers, and the Ohio Electric Lighting Association of Engine Builders, as well as a number of lectures to engineering students.

GENERAL NOTES

STUDENT BRANCHES

The following reports have come to the Society concerning the activities of its Student Branches:

At Columbia University the following officers were elected recently: F. R. Davis, president, H. B. Egbert, vice-president, H. B. Jenkins, secretary, and F. T. Lacy, treasurer. Papers are read before the organization once a month.

At Brooklyn Polytechnic a number of new members were received at the meeting of December 4, and a lecture was delivered by H. A. Black, on Depreciation Principles and Methods.

The Mechanical Engineering Society of the Massachusetts Institute of Technology enjoyed a lecture on December 21 by Robert A. Shailer, on Tunnels and Tunnel Construction. The society conducts excursions from time to time to places of industrial interest. those lately visited being the Quincy Market Coal Storage and Warehouse Co.'s refrigerating plant and the factory of the Stanley Motor Carriage Company. The officers are Frederick A. Dewey, chairman, Donald V. Williamson, vice-chairman, Arthur P. Truette, secretary, and Luke E. Sawyer, treasurer.

On December 3, the recently organized branch at the University of Cincinnati elected as temporary officers H. B. Cook, chairman, and P. G. Haines, secretary.

The Club of Mechanical Engineering of the University of Missouri, which was admitted at the last meeting of the Council on December 7 as a student branch of the Society, elected R. E. Dudley, president, Ernest C. Phillips, secretary-treasurer, and for members of the advisory board, Prof. E. A. Fessenden, Jun., Am.Soc.M.E., E. C. Phillips, and F. B. Thatcher. The club has as its honorary chairman Prof. Harry Wade Hibbard, Mem. Am.Soc.M.E.

Further statistics concerning these and other student branches are published on another page of The Journal.

ENGINEERS' CLUB BANQUET

The third annual banquet of the Engineers' Club took place Wednesday evening, December 22, with Mr. Andrew Carnegie, Honorary

Member Am.Soc.M.E., as the guest of honor. Mr. Carnegie mentioned his great pleasure in attending the dinner, an attendance which he regarded in the light of an obligation, and spoke again of his debt to the engineers and the chemists for their part in all his industrial success. He also repeated his prophecy that in the course of time Canada and the United States would be one nation.

This remark served to introduce another guest of the evening, Robert Cooper Smith, Esq. K.C., of Montreal, Quebec. Mr. Smith's address was an eloquent tribute to Mr. Carnegie. Mr. Martin W. Littleton followed and, in the absence of Hon. E. H. Gary, the speeches of the evening were concluded by Dr. Alex. C. Humphreys. Dr. Humphreys referred to the value of industrial education such as Mr. Carnegie is so successfully providing in the Carnegie Technical Schools at Pittsburgh, and reiterated his opinion that the educational work in America is too much influenced by the college, instead of training the average person for industrial life.

The attendance was nearly 200 and the excellence of the speeches and of the music, rendered by an orchestra under the direction of Hans Kronold, and the perfection of the menu and service made the occasion one of the most enjoyable and successful ever held by the Club.

DONATION TO THE LIBRARY

Clarence E. Kinne, Life Member, Am.Soc.M.E., in response to a request sent out through The Journal, has made up from his own files and sent to the Society the copies for 1894-1895, complete with index, forming vol. 1 of Machinery, which the Society had been unable to obtain through the customary channels. The volume has been placed in the Library, completing our files of this magazine to date.

REPRESENTATION AT FUNERAL SERVICES OF HORACE SEE

The President appointed James M. Dodge, Past-President, Rear Admiral George W. Melville, Past-President and Honorary Member, Oberlin Smith, Past-President, Fred. W. Taylor. Past-President, and J. Sellers Bancroft, Kern Dodge and Edward I. H. Howell, Honorary Vice-Presidents to represent the Society at the funeral services of Horace See, Past-President, Am.Soc.M.E., Thursday, December 16, 1909, at St. Peter's Church, 4th and Pine Sts., Philadelphia, Pa.

OTHER SOCIETIES

AMERICAN EXPOSITION IN BERLIN

As the first all-American Exposition ever conducted in a foreign country, the exposition to be held in Berlin during the summer of 1910 will offer peculiar advantages to American manufacturers. A freight reduction of 30 per cent both ways, granted by the Hamburg-American and the North German Lloyd lines, the remission of customs duty by the German Government, and the existence of the German-American patent treaty, which relieves American inventors from the necessity of obtaining patents in Germany, are among the inducements offered to exhibitors. The date set for the opening is June 20, and the exposition will be in progress three months. The exhibits will be carefully classified, the present plans including sections to be devoted to inventions, transportation, social economy and industrial safety, agricultural implements, machinery of all kinds, etc. Germany in 1908 consumed American products to the amount of $276,922,089; to say nothing of her influence on the trade of Europe.

The American headquarters for the exposition are in the Hudson Terminal Building, 50 Church St., New York, James L. Farmer, General Secretary. Members of the Society acting on the advisory committee are, C. A. Moore, Francis H. Stillman, Ambrose Swasey; and on the general committee, James M. Dodge and Thomas A. Edison, Honorary Member.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

At a meeting of the American Institute of Electrical Engineers held in the auditorium of the Engineering Societies' building, December 16, a paper entitled Comments on Development and Operation of Hydroelectric Plants, was presented by Henry L. Doherty, Member Am.Soc.M.E. The meeting was under the auspices of the High-Tension Transmission Committee.

WESTERN SOCIETY OF ENGINEERS

The Western Society of Engineers has appointed the following as a committee to confer with the Chicago City Council and the Harbor Commissioner regarding harbor improvement and development: A. Bement, Mem.Am.Soc.M.E., *Chairman*, W. L. Abbott, Member of Council, Am.Soc.M.E., L. E. Ritter, E. C. Shankland, Mem.Am.Soc.M.E., Willard A. Smith.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

The annual meeting of the American Institute of Chemical Engineers was held at Philadelphia, Pa., December 8 to 10. The address of welcome was made by Mayor John E. Reyburn. The following papers were presented for discussion: Natural Draft Gas Producers and Gas Furnaces, Ernest Schmatolla; The Commercial Extraction of Grease and Oils, W. M. Booth; The Chemical Industries of America, Prof. Chas. E. Munroe; Multiple Effect Distillation, F. J. Wood, Mem. Am.Soc.M.E.; The Advantages of the Multiple Effect Distillation of Glycerine and Other Products, A. C. Langmuir; Reclaiming of Waste India Rubber, S. P. Sharples; Materials for Textile Chemical Machines, Fred. Dannerth; A Method for Smelting Iron Ore in the Electric Furnace, Edw. R. Taylor; Chemical Composition of Illinois Coal, and Heat Efficiency of Smokeless Combustion and Heat Absorbing Capacity of Boilers, A. Bement, Mem.Am.Soc.-M.E.

Excursions were made to the laboratories of the University of Pennsylvania and the Commercial Museum, the chemical works of Harrison Bros. & Co., the Torresdale Filtration Plant; the wool-degreasing plant of Erben, Harding & Co.; the Welsbach Light Company, the plant of the Camden Coke Company; the Trenton Potteries; the Hamilton Rubber Company; the Linoleum Works; the cement plant at Allentown, Pa.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION

The National Society for the Promotion of Industrial Education held its third annual convention at Milwaukee, December 2-4. The convention was opened with a public banquet at the Hotel Pfister, at which James O. Davidson, Governor of Wisconsin, presided. Addresses on the Economic Value of Industrial Education were made by Charles Van Hise, President of the University of Wisconsin, George

Martin, former secretary of the Massachusetts Board of Education, and Alex. C. Humphreys, Manager Am.Soc.M.E., President of Stevens Institute of Technology. Mr. Humphreys spoke particularly of the improvidence and superficial character of our educational processes which have built up a system that has the college as its goal, whereas in reality the masses need industrial training. The many are being sacrificed to the few.

Public meetings were held on the remaining days, at which National Legislation, Corporation Schools, Evening Schools, Industrial Education at Home and Abroad, and Intermediate Industrial Schools, were considered and discussed. Among those who addressed the gatherings were Willet N. Hayes, Assistant Secretary of Agriculture, John L. Shearer, President Ohio Mechanics' Institute, Arthur L. Williston, Mem.Am.Soc.M.E., Director in Pratt Institute, Mrs. Anna Garlin Spencer, Society for Ethical Culture, and Edgar S. Barney, Superintendent Hebrew Technical School for Boys. An exhibition of trade school work was conducted throughout the convention, some thirty prominent industrial institutions being represented.

The object of the society is to bring to public attention and to provide opportunities for the study of industrial education, as well as to make available the results of experience and to promote the establishment of additional institutions. Its work is carried on through a general office in New York and through State branches and committees. The New York State Branch has as its president James F. McElroy, Mem.Am. Soc.M.E., and as its secretary Prof. Arthur L. Williston, Mem.Am.Soc.M.E.

NATIONAL COMMERCIAL GAS ASSOCIATION

The fourth annual meeting of the National Commercial Gas Association occupied Madison Square Garden from December 14 to 22. One of the greatest undertakings of the exhibition committee was the piping of the entire building, making possible the most extensive and successful gas and gas appliance exhibition ever held. Among papers presented were: The Future of Gas for Street Lighting, E. N. Wrightington; The Use of Gas for Industrial Purposes, Present and Future, S. T. Wilson; The Application of Architectural Designs to Gas Fixtures, L. F. Blyler; Theory of Combustion, T. O. Horton; Gas Engines in Competition with Central Station Electric and Isolated Steam Plants, W. W. Cummings, Mem.Am.Soc. M.E.; General Maintenance and Special Troubles, R. H. Thomas;

Water Heaters, G. W. Savage. On December 17 a joint meeting of the Association with the New York Section of the Illuminating Engineering Society was held.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

The seventeenth annual meeting of the Society of Naval Architects and Marine Engineers was held at the Engineering Societies Building, New York on November 18 and 19. Among the papers presented for discussion were the following: The Foreign Trade Merchant Marine of the United States; Can it Be Revived? by G. W. Dickie, Mem.Am.Soc.M.E.; the Evolution of Screw Propulsion in the United States, by Chas. H. Cramp; The Effect of Parallel Middle Body upon Resistance, by D. W. Taylor; The Applications of Electricity to the Propulsion of Naval Vessels, by W. L. R. Emmet, Mem.Am.Soc.M.E.; The Strength of Water-tight Bulkheads, by Prof. William Hovgaard; The Design of Submarines, by M. F. Hay.

The officers elected are: president, Stevenson Taylor, Mem.Am. Soc.M.E.; vice-presidents, J. W. Miller, Rear-Adm. Geo. W. Melville, Hon. Mem.Am.Soc.M.E.; Members of Council, Wm. J. Baxter, Geo. W. Dickie, Mem.Am.Soc,M.E.,W. D. Forbes, Mem.Am.Soc. M.E., Andrew Fletcher, Mem.Am.Soc.M.E., H. A. Magoun, Mem. Am.Soc.M.E., Lewis Nixon; Associate Members of Council, J. S. Hyde, Assoc.Am.Soc.M.E., C. B. Orcutt.

ENGINEERS' CLUB OF ST. LOUIS

At the annual meeting of the Engineers' Club of St. Louis, held in the club rooms on December 1, 1909, reports covering the work of the year were presented, and the following officers placed in nomination and ordered to ballot: President, M. L. Holman, Past-President, Am.Soc.M.E.; vice-president, J. D. Von Maur; secretary-librarian, A. S. Langsdorf; treasurer, C. M. Talbert; directors, J. W. Woermann and H. J. Pfeifer; members of the board of managers, Association of Engineering Societies, John Hunter, Montgomery Schuyler, J. F. Bratney.

The business of the evening was followed by an illustrated address on Reinforced-Concrete Construction by A. J. Widmer, of the Trussed Concrete Steel Company.

BROOKLYN ENGINEERS' CLUB

The Brooklyn Engineers' Club held its annual meeting in the club-house, 117 Remsen St., on December 9. The annual reports of the various committees and the Board of Directors were read. Upon motion it was voted that the election of the new board of officers take place during the annual dinner, Thursday, December 16, at which time the following were elected: President, George A. Orrok, Mem.Am.Soc.M.E.; secretary, Joseph Strachan; treasurer, William T. Donnelly, Mem.Am.Soc.M.E.; directors, William Andrews, Frederick C. Noble; auditing committee for one year, Fred. L. Cranford, Jacob Schmitt, Geo. A. Hartung. During the afternoon and evening of the same day, the first annual loan exhibition of the scientific books of the year, photographs and plans of engineering work was opened.

NECROLOGY

HORACE SEE, PAST-PRESIDENT, AM.SOC.M.E.

The sudden death of Horace See, Past-President, Am.Soc.M.E., December 14, 1909, is announced. An account of his life will appear in an early number of The Journal.

The death of Dr. Charles B. Dudley, member of the Research Committee of the Society, December 21, 1909, is announced. An account of his life will appear later.

CHARLES HENRY WILLCOX

Charles Henry Willcox died at his home in Westport, Conn., on September 13, 1909. Mr. Willcox was born in Little Falls, N. Y., on March 31, 1839, and was the son of James Willcox, founder and president of the Willcox & Gibbs Sewing Machine Co. He entered his father's business at the age of eighteen and was continuously connected with the company as mechanical engineer from 1866 until his retirement a few years ago, and most of that time as director. The natural bent of his mind was toward mechanics and in collaboration with James E. A. Gibbs he developed and placed on the market the invention of the single-thread chain-stitch sewing machine, which is now so widely used in the making of wearing apparel. Other patents followed, in particular that of the automatic tension, which it is said consumed ten years of patient experimentation before it was perfected. Mr. Willcox was also the inventor of two straw-hat sewing-machines, one the American straw hat machine in which the stitch is visible, and another in which the stitch is concealed. These two machines are used to-day in the manufacture of fully 90 per cent of all straw hats made. The knit goods manufacturing field also received an impetus through the invention of the Willcox & Gibbs hosiery trimming machine. The overlock machine worked out by Mr. Willcox in collaboration with the late Stockton Borton, was a great advance over the hosiery trimming machine and is recognized as one of the finest mechanical productions

in sewing machines. Through the ornamental character of its stitch it has been adopted in lines of manufacture other than that for which it was originally intended.

In addition to his connection with the Willcox & Gibbs Sewing Machine Co., Mr. Willcox was for forty years affiliated with the Brown & Sharpe Mfg. Co. He was a life member of the Society.

CHARLES SWINSCOE

Charles Swinscoe, consulting engineer of the Clinton Wire Cloth Company, Clinton, Mass., was born at Nottingham, England, January 1, 1833. His early education was received in the Collegiate School, Manchester, England. He came to this country when a lad and at one time was Fourth Officer on the Dreadnought under Capt. Samuel Samuels.

From 1851 to 1854 Mr. Swinscoe studied practical mechanics in his father's shop. In 1867 he established the steam pump works of the Geo. F. Blake Mfg. Co., at Boston, designing most of the work. In 1876 he left this company to take charge of the Reading Hydraulic Works, designing its steam pumping machinery. From 1878 to 1880 he was in charge of the Bay State Brick Company and after that date of the Clinton Wire Cloth Company. In 1903 he became consulting engineer of this company.

Mr. Swinscoe was a musician of ability and was president of the Clinton Choral Union and organist of the Episcopal Church for many years. He was a member of the Clinton Historical Society, and a member of this Society since 1887.

PERSONALS OF THE MEMBERSHIP, AM. SOC. M. E.

Ludwell B. Alexander has assumed the position of vice-president of the Haggerty Contracting Company, Bronx Borough, New York. He was formerly associated with the United Engineering and Constructing Company, New York, as assistant engineer.

Thomas Appleton, formerly connected with the East St. Louis, Ill., office of the U. S. Public Buildings, as superintendent of construction, is now identified with the Alton, Ill., office.

Adolph O. Austin, chief draftsman of the Starr Engineering Co., New York, has accepted a position with the Vilter Mfg. Co., Milwaukee, Wis., in the capacity of assistant engineer.

C. Kemble Baldwin, formerly chief engineer of the Robins Conveying Belt Company, and for the past two years chief engineer of the Robins New Conveyor Company, has been appointed chief engineer of the Robins Conveying Belt Company, the two companies having been consolidated. Mr. Kemble lectured on The Belt Conveyor, on November 10, before 400 members of the first class of the engineering course of the University of Illinois.

A. Bement presented papers on Chemical Composition of Illinois Coal, and Heat Efficiency of Smokeless Combustion and Heat Absorbing Capacity of Boilers, at the December 8–10 convention of the American Institute of Chemical Engineers, held in Philadelphia, Pa.

Paul P. Bird presented a paper on The Smoke Problem of Chicago at the November 17 meeting of the Western Society of Engineers.

Walter J. Bitterlich, formerly machine designer with the Bresnahan Shoe Machinery Company, Lynn, Mass., has accepted a position with the Hood Rubber Company, Watertown, Mass., to act in the capacity of chief draftsman.

Paul M. Chamberlain has resigned the position of chief engineer of the Underfeed Stoker Company of America, Chicago, Ill., to take up private practice. His office will be in the Marquette building, Chicago, Ill.

Chas. C. Christensen contributed an article on A One Hundred Ton Modern Cyanide Plant to the November 13 issue of *The Mining World*.

H. V. Conrad has accepted a position with the Westinghouse Air Brake Company, Wilmerding, Pa.

George L. Crook, recently in charge of the manufacturing organization in the E-M-F plant at Detroit, Mich., has entered the employ of the M. Rumely Co., La Porte, Ind., as works manager.

Henry L. Doherty presented a paper entitled, Comments on the Development and Operation of Hydro-Electric Plants, at the December 16 meeting of the American Institute of Electrical Engineers.

Carl S. Dow contributed an article on The Fuel Economizer to the December issue of *The Practical Engineer.*

Frank B. Gilbreth is the author of a book on Bricklaying System.

Charles A. Hague delivered a lecture on The Development of the Pumping Engine, at the Sheffield Scientific School, Yale University, New Haven, Conn., November 12.

An article on Errors in Grinding Tapered Reamers and Milling Cutters, by H. A. S. Howarth, was published in the December number of *Machinery.*

Prof. Fred. R. Hutton delivered a lecture, on November 9, on Some Problems of the Large Gas Engine, before the Stevens Institute Engineering Society, affiliated with The American Society of Mechanical Engineers. Professor Hutton has been invited to give a lecture before the Graduate School of Marine Engineering, U. S. Naval Academy, Annapolis, in January.

A. Lewis Jenkins has contributed an article on Stresses due to Bending and Twisting and the Design of Shafting, to the November 12 issue of *Engineering* (London).

Charles Kirchhoff, who has been connected for almost thirty years with *The Iron Age,* and the other publications of the David Williams Company, has disposed of his interests in that company and retired from active business.

George L. Knight delivered a lecture on The Generating and Distributing System of the Brooklyn Edison Company, at the November 6 meeting of the Brooklyn Polytechnic Student Branch of the Society.

Prof. A. G. Koenig delivered an illustrated lecture on Refrigeration before the December 7 meeting of the Modern Science Club.

J. W. Lieb, Jr., delivered a lecture, December 10, before the Electrical Engineering Society of Columbia University, the subject being Electric Light.

John McGeorge and H. W. Woodward have formed a consulting firm under the name of the Cleveland Engineering Company, with offices in the New England Building, Cleveland. Mr. McGeorge has been chief engineer of the Wellman-Seaver-Morgan Co., Cleveland, O.

A biographical sketch of Spencer Miller was published in the December issue of *Cassier's Magazine.*

David M. Myers contributed an article on Burning Natural Gas as Boiler Fuel to the December 7 issue of *Power and the Engineer.*

E. W. Nicklin, recently identified with the Diamond Power Specialty Company, Detroit, Mich., has accepted a position with the Detroit Brass Works, Detroit, Mich.

George A. Orrok lectured before the Student Section of The American Society of Mechanical Engineers at Columbia University on the evening of December 3 on Gas Engine and Blast Furnace Practice. At the December 21 meeting of the Modern Science Club, Mr. Orrok delivered a lecture on Surface Condensers. Mr. Orrok has been elected president of the Brooklyn Engineers' Club.

Thos. C. Pulman, formerly manager in India for the Worthington Pump Company, Ltd., and James Simpson & Co., Ltd., subsidiary companies of the International Pump Co., of New York, has been appointed to the London offices of the companies, to supervise the Indian and Eastern business, and will be attached to the sales department.

R. H. Rice addressed a joint meeting of the Electrical Section of the Western Society of Engineers and the Chicago Branch of the American Institute of Electrical Engineers, December 22, on Low Tension Feeder Systems for Street Railways.

Morris DeF. Sample, formerly manager of department, National Patent Holding Company, Chicago, Ill., has become associated with The Fire Protection Company, Indianapolis, Ind., as secretary-treasurer.

Charles M. Schwab has been elected a trustee of Lehigh University.

O. G. Smith, associated with the Platt Iron Works Company, Dayton, O., has been made manager of the company's branch house at St. Louis, Mo.

Arthur C. Tagge, formerly identified with the Eastern Canada Portland Cement Co., Dombourg, P. Q., has become associated with the Canada Cement Co., Montreal, P. Q.

Stevenson Taylor has been elected president of the Society of Naval Architects and Marine Engineers.

Edward P. Thompson, formerly of New York, has moved his business to Washington, D. C., in order to be near the Patent Office in behalf of clients.

S. K. Thompson, formerly master mechanic with Stanley G. Flagg & Co., Philadelphia, Pa., has established an office in the Real Estate Trust Building in that city as consulting mechanical engineer.

S. Tompkins, who has been in charge of the shops and engineering department of the Miller School in Virginia, has been appointed superintendent of power

stations and chief engineer of shops and track, of the Coney Island & Brooklyn R. R., Brooklyn, N. Y.

Walter H. Trask, Jr., has been appointed district sales manager of the Denver Engineering Works Company, Salt Lake City. He was formerly assistant to sales manager in the company's main office in Denver.

F. J. Wood presented a paper on Multiple-Effect Distillation at the December 8 to 10 meeting of the American Institute of Chemical Engineers, held in Philadelphia, Pa.

THE PROFESSION OF ENGINEERING

PRESIDENTIAL ADDRESS 1909

By President Jesse M. Smith, New York

Great engineering works existed in many parts of the world long before Columbus discovered America. We have but to consider the ruins left by the Incas in South America and the Aztecs in Mexico to realize the great work done on this continent in engineering. In Asia the great wall of China, the temples of Japan, China, Babylonia and Assyria bear record of the presence of the engineer.

2 In Africa, the vast pyramids of Egypt and the temples on the Nile are evidences that great engineers existed long before the Christian era. We marvel still when contemplating the pile of immense blocks of stone forming the pyramids and try to imagine what form of apparatus could have been used in placing those great stones one upon the other.

3 In Europe the Greeks and Romans did marvelous work in roads, bridges, aqueducts, and various mechanical structures which the modern engineer may well ponder upon and admire. While we read much in history of the emperors and kings who reigned when these great engineering works were produced, we learn little of the men who produced them, men whom we now call engineers.

4 While engineers have existed for thousands of years it is only within a comparatively recent time that they have begun to form themselves into societies for their mutual education and the advancement of the profession of engineering.

5 In England, as early as 1771, Smeaton and his contemporaries came together to form the Smeatonian Society of Engineers; which, therefore, according to the calculations of a noted English engineer, is five years older than the United States. The Institution of Civil Engineers of Great Britain came into existence in 1818, and was followed by its sister society, the Institution of Mechanical Engineers, in 1847. La Société des Ingénieurs Civils de France was founded in 1848. Die Verein Deutscher Ingenieure was organized in 1856.

Presented at the Annual Meeting of The American Society of Mechanical Engineers, December 1909.

6 In this country the Boston Society of Civil Engineers began its work in 1848. Our elder sister among national societies, the American Society of Civil Engineers, was organized in 1852. The next member of the family, the American Institute of Mining Engineers, was born in 1871. Our own Society came into existence in 1880, and our younger and very vigorous sister, the American Institute of Electrical Engineers, came along in 1884.

7 Each of these four national societies, the American Society of Civil Engineers, the American Institute of Mining Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical Engineers, has grown greatly since its organization, and each continues to thrive. During the process of upbuilding of these four great national societies, several other national societies of specialists in engineering and many local societies of engineers have been formed, and all of these also are active and thriving.

8 The four greater national societies have an aggregate membership at this time of over 19,000 members. Twelve national societies of engineering specialists contain more than 13,000 members. Twenty-three local engineering societies in different cities of the United States count over 8,600 in their membership.

9 What does this great army of over 40,000 engineers, organized into many different societies, all for purely professional purposes, mean? It means that the engineering profession is making itself felt in this country of ours,—that it proposes to take a prominent place in the great activities by which the country is being developed,—that it will take its place in public affairs,—that it is coming into its own.

10 The national societies are not antagonistic to each other; on the contrary, they support and give confidence to each other. The national societies of specialists are not at war with the other national societies; they supplement them.

11 The local societies are not in opposition to the national societies; they extend their influence; they are the outposts of the great army. The specialists do not interfere with each other. We are all specialists to a greater or less extent; but we are all *engineers.*

12 In the legal profession, some men practice in the criminal courts: others devote themselves to titles in real estate; others are in corporation law; others practice in patent causes; they all squabble with each other in their practice; but when they meet in their bar associations they are all lawyers; they stand by each other and their profession; they are a power in the world.

13 The medical profession is made up of surgeons, oculists, aurists, general practitioners, specialists of the skin, the heart, the lungs and every other part of the human anatomy; but when they come together in their general medical associations they are all doctors; they also stand by each other and their profession; they also are a power in the world.

14 In the engineering profession why may not the men who practice in steam engineering; in machine construction; in hydraulics; in railroad, bridge, mining, electrical and chemical engineering; in metallurgy, refrigeration, heating and every other specialty in engineering, come together, stand by each other and their profession, become known as *engineers* and be a power in the world?

15 When, in 1889, the Institution of Civil Engineers of Great Britain invited the four national American societies of civil, mining mechanical and electrical engineers to visit it in London, there was inaugurated a spirit of friendship and coöperation in the engineering profession which has grown stronger and stronger as the years have passed. Following the visit in London, La Société des Ingénieurs Civils de France, in the same year, invited the American societies to Paris.

16 Those who were fortunate enough to participate in those memorable demonstrations of hospitality cannot fail to realize how greatly the seed of coöperation sown in that year has fructified.

17 In 1900 this Society was again invited by the Institution of Civil Engineers and the Institution of Mechanical Engineers to visit them in England, and again invited by the French society to visit it in Paris. Thus the spirit of coöperation was still further advanced by these remarkable meetings. On both occasions the sister societies abroad were untiring in the entertainment of the American engineers.

18 The year 1904 was made memorable by the acceptance of an invitation extended by this Society to the Institution of Mechanical Engineers of Great Britain to hold a joint meeting in Chicago. Thus the spirit of coöperation and good friendship was again strengthened and extended.

19 Now the Institution of Mechanical Engineers of Great Britain has expressed the desire to still further promote this friendly spirit by inviting this Society to a joint meeting in July of 1910 in England. The Council of our Society has accepted this very cordial invitation of the Institution in the spirit of good will in which it was extended. It remains for the membership of The American Society of Mechani-

cal Engineers to respond to this spirit and to go to England next year with its best talent and its best men.

20 The helpful coöperation in professional work which has already been established with our sister societies over the seas is also becoming manifest in our own country. The four national societies of civil, mining, mechanical and electrical engineers on March 24, 1909, held in this auditorium a joint meeting on the "Conservation of the National Resources," which did much to bring engineers close together and into coöperative relation.

21 Our Society invited the Boston Society of Civil Engineers to join in the monthly meetings of the Society recently held in Boston. The Engineers' Club of St. Louis in like manner was asked to join with us in the Society's monthly meetings recently held in St. Louis. In both cases the invitations have been accepted in the best spirit of coöperation.

22 The engineering societies of the country may be likened to the members of a large and harmonious family, each member independent to do its own special work in its own way, each member ready to help each of the others, each residing in its own home, but all ever ready to stand by each other, to work for the common good, to advance and dignify the profession of engineering.

23 A striking example of the "getting together" of the engineering societies is found in this building which is the home of our Society. It is also the home of our sister societies, the American Institute of Mining Engineers and the American Institute of Electrical Engineers.

24 Under the same roof are grouped together fifteen other societies of engineering and allied arts. 25,000 engineers practicing in all the specialties of engineering may call this building their professional home. We are living together here in peace and harmony. We have brought our books together into a single library open to the profession and to the public, where every person is welcome.

25 Our meetings are held in the same auditorium and lecture halls; the doors stand open that all who wish may enter. Our professional brethren of every society of every country are welcome here. The large hall at the entrance to the building is a foyer where all engineers may come together on the same plane, where they may unite to strengthen each other, to sustain and advance the profession of which they form a part.

26 The spirit of coöperation which now exists must be fostered, strengthened, made enduring, to the end that as great solidarity will

exist in the engineering profession as exists in any of the other great learned professions.

27 Numbers in membership are, of course, important in the societies which represent the engineering profession, but a high standard of membership is of much greater importance.

28 With a considerable number of high-grade technical schools throughout the country all striving with each other to raise the standards of engineering education ever higher and higher; and with the graduates from these institutions taking, from year to year, a larger and more responsible part in the great activities of the country, there is no lack of high-grade material from which to form a membership in the engineering societies which will be worthy of the profession.

29 In the Institution of Civil Engineers, as well as in the Institution of Mechanical Engineers, of Great Britain, we are informed, no person is admitted into the lower grade of membership unless he can pass a satisfactory examination as to the fundamental principles of engineering, by an examining board of the Institution. The rules laid down by this examining board form the standard by which the applicants to membership are measured. If the technical schools in Great Britain maintain an equally high standard in granting their degrees in engineering, then the degree may be accepted in lieu of an examination.

30 In other words, the engineering institutions in Great Britain establish the standard for the degrees granted by the technical schools. A promotion from a lower to a higher grade of membership is only made upon a showing of sufficient experience in engineering to satisfy the rules laid down by the Institution.

31 In The American Society of Mechanical Engineers, a person may enter the Society as a Junior upon the presentation of a degree in engineering from a technical school. But this Society has not, up to the present, established a standard by which to measure that degree. I believe the standard for such a degree in engineering should be established by the Society, and that it should be as high as that of the best schools of engineering in this country. It will follow that the schools having a lower standard will soon be brought up to the higher standard.

32 Promotion to higher grades of membership in our Society is only made upon a showing of engineering experience satisfactory to our Membership Committee. This committee is maintaining a high standard of membership, and I believe that acting under the influence of the membership and the Council of the Society, it will not allow that standard to fall, but rather cause it to rise,

33 If we are to have a profession of engineering, as distinguished from the trade of engineer, we must have a broad education befitting men of a learned profession, as distinguished from a narrower education sufficient for men of a trade.

34 President Lowell of Harvard in his recent remarkable inaugural address, gave this as his conclusion: "The best type of liberal education in our complex modern world aims at producing men who know a little of everything and *something well*." If that conclusion be true of a liberal education leading to the learned profession of the law or medicine or theology, why is it not also true of a scientific education leading to the learned profession of engineering?

35 If preponderance be given to one part of President Lowell's conclusion over the other part, certainly knowing "a little of everything" leads to superficiality; while just as surely knowing but one thing well leads to narrowness. There would seem to be a happy mean between these two extremes, in the education of the engineer.

36 The engineer capable of being at the head of the larger engineering works must know something of many things, several things well and one thing profoundly.

37 The engineer president of a great railway system, for example, must know *something* of the alignment and gradients of the permanent way, its construction and maintenance; *something* of the proper location of sidings and stations; *something* of the system of signals, of the various kinds of cars, of the quality of water for the locomotives, of the heating and lighting of cars, and many other things. He must know *well* that the bridges have been designed for safety and endurance and that they have been properly constructed. He must know *well* that the tunnels are safely protected against external pressure and falling rocks. He must know *well* that the locomotives for drawing the high-speed trains, as well as those for the heavy freight trains, are of the very best design and capable of performing their duty with efficiency, economy and endurance. He must know *well* how to manage the traffic and keep the accounts. He must know *profoundly* how to coördinate all the different parts of this complex organization so that each part will perform its proper and full function, to the end that passengers and freight will be carried safely, surely, quickly and cheaply, and also that dividends will be paid to the shareholders.

38 The engineer knowing something of many things, several things well and one thing profoundly, is still one-sided if all this knowledge is confined strictly to his profession. He will be a much

broader man and a better engineer, if in his leisure hours he can turn his thoughts entirely away from his professional work and toward those things in nature and art which give that rest and renewal of the professional mind necessary to continued work.

39 Engineers have known for many years that the profession of engineering is a learned profession; the rest of the world is rapidly arriving at the same conclusion.

40 When in April, 1907, this building was dedicated "To the advancement of Engineering Arts and Sciences," President Hadley of Yale, where the learned professions have been taught for nearly 200 years, said:

> The men who did more than anything else to make the nineteenth century different from the other centuries that went before it, were its engineers.
>
> Down to the close of the eighteenth century the thinking of the country was dominated by its theologians, its jurists, and its physicians.
>
> These were by tradition the learned professions, the callings in which profound thought was needed, the occupations where successful men were venerated for their brains.
>
> It was reserved for the nineteenth century to recognize the dominance of abstract thought in a new field—the field of constructive effort—and to revere the trained scientific expert for what he had done in these lines.
>
> Engineering, which a hundred years ago was but a subordinate branch of the military art, has become, in the years which have since elapsed, a dominant factor in the intelligent practice of every art where power is to be applied with economy and intelligence.

It is encouraging to engineers to have their profession recognized as a "learned profession" by so great an authority as the president of Yale University.

41 Enthusiasm and devotion to his profession is characteristic of the engineer, and from my observation these begin with the student in engineering and extend right through his life. President Wilson of Princeton, in an address at Harvard not long since, dwelt upon "the chasm that has opened between college studies and college life. The instructors believe that the object of the college is study, many students fancy that it is mainly enjoyment, and the confusion of aims breeds irretrievable waste of opportunity." These conditions, I believe, exist to a much smaller extent in the technical schools, where engineers are taught, than in the general colleges, where a liberal education is obtained.

42 Enthusiastic love of work, for his profession's sake, resides in the heart of the engineer who becomes great. The man who merely works for wages, and without enthusiasm, does not rise; he remains a paid servant, and poorly paid at that.

43 Where enthusiasm exists, love of work exists; success follows. Our individual enthusiasm is quickened by the study of the work of our brother engineers.

44 What engineer while being whisked through the tunnels which connect Manhattan Island with the lands surrounding it, can fail to rejoice in his profession as he contemplates the work of the civil engineers, the mining engineers, the mechanical engineers, the electrical engineers, which, joined together, supplemented each other to produce success in those marvelous undertakings? The highest knowledge and skill in each of the four branches of the engineering profession were called for, and were forthcoming, in the consummation of this great work. It is not a question of which engineers did the most toward the success of this problem in transportation; they all did their best; they all did well; each contributed a necessary part to the success; they were all engineers working for the advancement of the profession of engineering.

45 Will not every true engineer feel his enthusiasm in his profession quicken, as he watches the great vessels of trade and the great vessels of war sweep out to sea, and he stops to consider how much of brains, and long experience, and hard work of many men are concentrated in each one of them?

46 We marvel still, our enthusiasm is inspired, as we see ponderous steam locomotives and mysterious electric locomotives competing in the hauling of trains, ever heavier and heavier, ever faster and faster, and both succeeding.

47 The automobile in its present highly developed and thoroughly practical form is the result of enthusiastic work of many engineers principally within the last fifteen years.

48 The enthusiasm of the engineer is never satisfied. Having conquered the highway with the automobile driven by the internal combustion gas engine, he now proposes to conquer the air with the aëroplane driven by the same kind of an engine in improved form.

49 The American Society of Mechanical Engineers has before it a future of usefulness to its members and influence in the profession, which is unlimited. It only requires that we stand by our tradition of increasing the membership with men of high quality as engineers; that the members maintain enthusiastic devotion to good professional work; that they coöperate with each other in the broadest and most friendly spirit to produce that solidarity of membership, and devotion to high ideals, which will compel the world to class the profession of engineering with the other learned professions.

EXPERIMENTAL ANALYSIS OF A FRICTION CLUTCH-COUPLING

By Prof. Wm. T. Magruder, Columbus, O.

Member of the Society

The following series of experiments was recently made to determine the results from the application of a known force at the end of the shifter lever of a friction clutch-coupling. Several 24-in., four-jaw friction clutch-couplings were used. They were the stock couplings made by the Falls Rivet & Machine Company, of Cuyahoga Falls, O. They consisted of the usual shifter lever, fork, yoke and cone, sliding on the driving shaft. The clutch arm *G*, Fig. 1, was a heavy casting keyed to the shaft *D*. Guide surfaces *H* were machined in each arm of the casting *G*, in which slid the inner jaws *I* and the outer jaws *J*. Each of the four pairs of jaws *I* and *J* was connected by pins *K* to the wedge-block *L*, which was fulcrumed at its center *M* in the clutch-arm casting. The wedge-blocks *L* carried adjustable steel wedges *N*, whose inner ends *O* engaged the short and hardened ends *P* of the cone-levers *Q*, and whose longer ends *R* were operated through the double links *F* by the sliding cone *E*. The inner and outer jaws engaged the annular ring *S* which was keyed to the driven shaft. This ring was 24 in. external diameter and 23 in. internal diameter. The eight jaws were each lined with a maple block 2½ in. by 9 in. in size.

2 The tests included five lines of investigation:

First: To determine the forces required to throw in the shifter lever at different speeds when the clutch was in motion and when the clutch was at rest, and before and after the load had caused the clutch to slip on the ring.

Second: With different adjustments of the wedges, to determine the relation of the forces applied at the end of the shifter lever at different points in its motion and the cor-

responding axial forces, to the forces caused thereby to be exerted by the clutch shoes upon the ring of the clutch pulley.

Third: To determine the frictional resistances between the clutch shoes and the ring of the clutch-coupling, in motion and at rest under different loads.

Fourth: To determine the power transmitted for different adjustments of the wedges corresponding to different forces required to throw in the shifter lever, including the

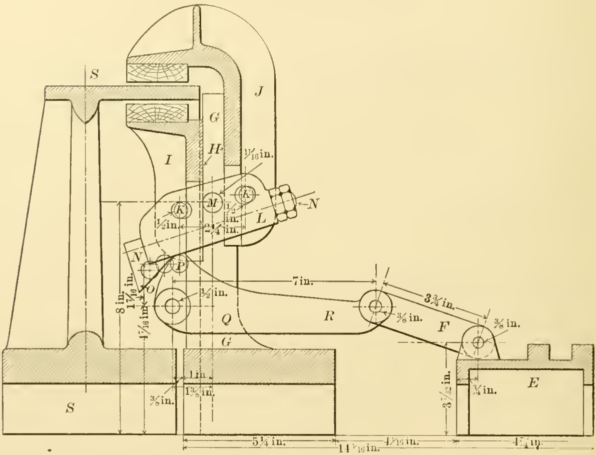

Fig. 1 Half Section of Friction Clutch-Coupling.

maximum power which the clutch was capable of transmitting, and the maximum power which it was capable of picking up from rest.

Fifth: To determine the relation of the maximum forces applied at the end of the shifter lever, and the corresponding axial forces, to the maximum power transmitted by two-arm and four-arm clutches for the same adjustment of the wedges.

3 To make these tests, two machines were designed and constructed, as follows:

DYNAMIC CLUTCH-TESTING MACHINE

4 To determine the maximum power which a clutch was capable of transmitting when the load was either gradually applied or picked up from rest, the dynamic clutch-testing machine, Fig. 2, was used. It consisted of floor-stands *U*, two co-axial shafts *D* and *T*, $3\frac{7}{16}$ in. in diameter, and a large belt pulley *V* on the end of the driving shaft *D*, to which power was delivered. The clutch-coupling *G* was placed near the middle at the junction of the two shafts. The coupling was keyed to the driving shaft *D*, and the clutch-ring *S* was keyed to the driven shaft *T*. On the opposite end of the driven shaft the brake pulley *W* was keyed. The shifter-lever *A* was operated in a horizontal plane. The motions required to throw in the clutch-cone *E* were measured. The lever *A* was operated by hand power, or by screw power *B*, from behind a screen *Y* made of planks and used for the protection of the persons engaged in the test. There was a horizontal slit in it for the motion of the lever.

5 To measure the force exerted on the end of the shifter lever, a calibrated spring-balance *X* was used. It was of 300 lb. capacity, and was graduated by 5-lb. divisions.

6 The power was absorbed by a prony brake *Z* from the internally flanged, flat-faced pulley *W*, 48 in. in diameter, and 24 in. face. The length of the brake arm *Z* was $72\frac{5}{32}$ in. The brake constant was 0.001145 b.h.p. per lb. per revolution. The effort exerted by the brake beam was measured by a platform scale *C* of 2000 lb. capacity. The leverage of the shifter lever *A*, when normal to the shaft *D*, was 4.939 in the dynamic clutch-testing machine. It is to be regretted that the power available was not sufficient to keep the speed uniform at 100 r.p.m., and for this reason the machinery slowed down to 92 r.p.m. under the heaviest loads.

STATIC CLUTCH-TESTING APPARATUS

7 In order to determine the force with which the shoes pressed against the clutch ring when a given maximum force was required to throw the shifter lever into operation, a static clutch-testing apparatus, Fig. 3 and Fig. 4, was used. It consisted of a clutch arm *G* mounted on a vertical shaft *D* supported in a flange coupling fixed to a structural steel frame *a*. Only the two opposite arms of the clutch were used in this apparatus. The inner jaws were removed. The shoes of the two outer jaws *J* were caused to press upon a dummy

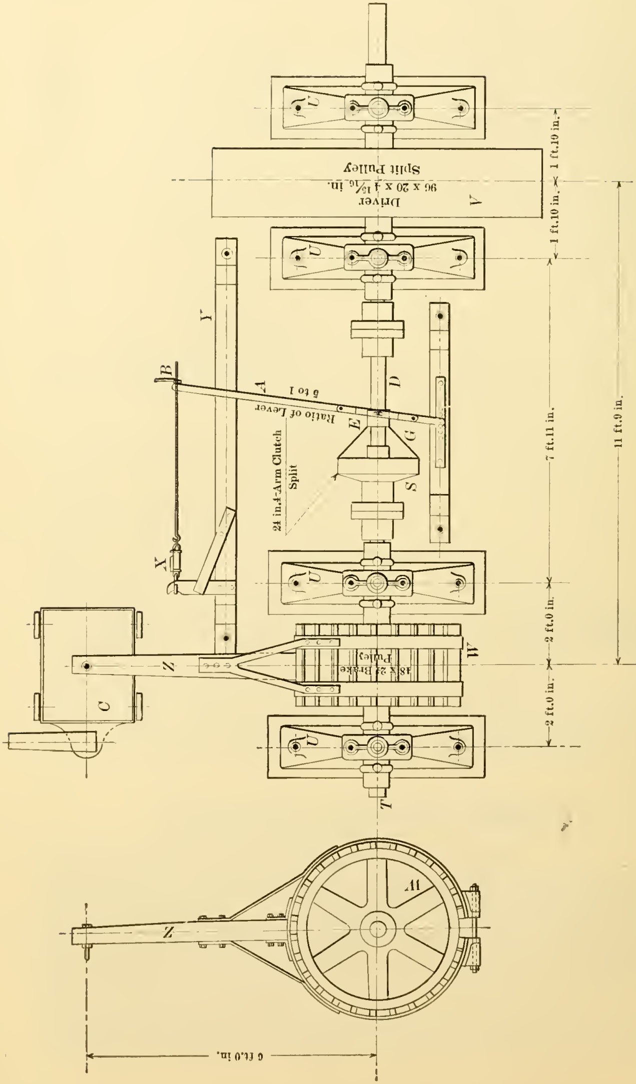

FIG. 2 DYNAMIC CLUTCH-TESTING MACHINE

ring made up of two separate cast-iron segments b. Each of these segments was connected by the links c to the yoke d, which in turn was connected through turnbuckle e to an eye carrying double knife edges f, which engaged the short and vertical end g of a bell-crank lever fulcrumed on a knife edge h in the frame a of the apparatus. To the longer and horizontal arm i of the bell-crank lever was knuckled a vertical prop j, the lower end of which was conical and which bore in a center-punch mark made in an iron bar resting upon a platform scale k, of 600 lb. capacity. The ratio of the arms was seven. Two platform scales were used, one for each dummy ring segment.

8 The parts of the mechanism were adjusted so that the knife edges were kept in position and bore fairly. The ring segments were so located that their external diameter was 24 in., or the same as the clutch ring. This was done by means of the turnbuckles. When the ring segments were in this position the wedges were adjusted to make the maple shoes bear evenly. The shifter lever was thrown in by screw power B and the force so required was measured frequently at definite intervals which were determined by measuring the distances which the cone E had been moved from its original position. The leverage of the shifter lever A, when normal to the shaft, was 4.863 to 1 in this apparatus.

9 In using the dynamic clutch-testing machine, the maple shoes were first adjusted by means of the wedge nuts so that they bore evenly. They were then burned in by driving the shaft D and the coupling G while the ring S was prevented from rotating. The wedge nuts were then adjusted again to make the shoes of both outer and inner jaws bear evenly on the ring when the shifter lever was thrown in.

10 This adjustment was tested by means of 16 copper strips, $\frac{1}{2}$ in. wide, 0.002 in. in thickness, one used at each end of each shoe. If the shoes did not bear evenly, or at least as well as they are supposed usually to do in ordinary good millwright's practice, the wedge nuts were screwed up, the ring blocked from rotating, the lever thrown in, and the shoes again burned in. By this means fairly uniform results and even pressures were obtained between the eight shoes and the ring. With the shifter lever thrown in and the copper strips just capable of being pulled out by hand, the counting of the rotations of the wedge nuts was begun. Similar adjustments were made on the static clutch-testing apparatus, except that the shoes had been surfaced but not burned in.

11 In the tests, the wedge nuts were all screwed up, one turn or

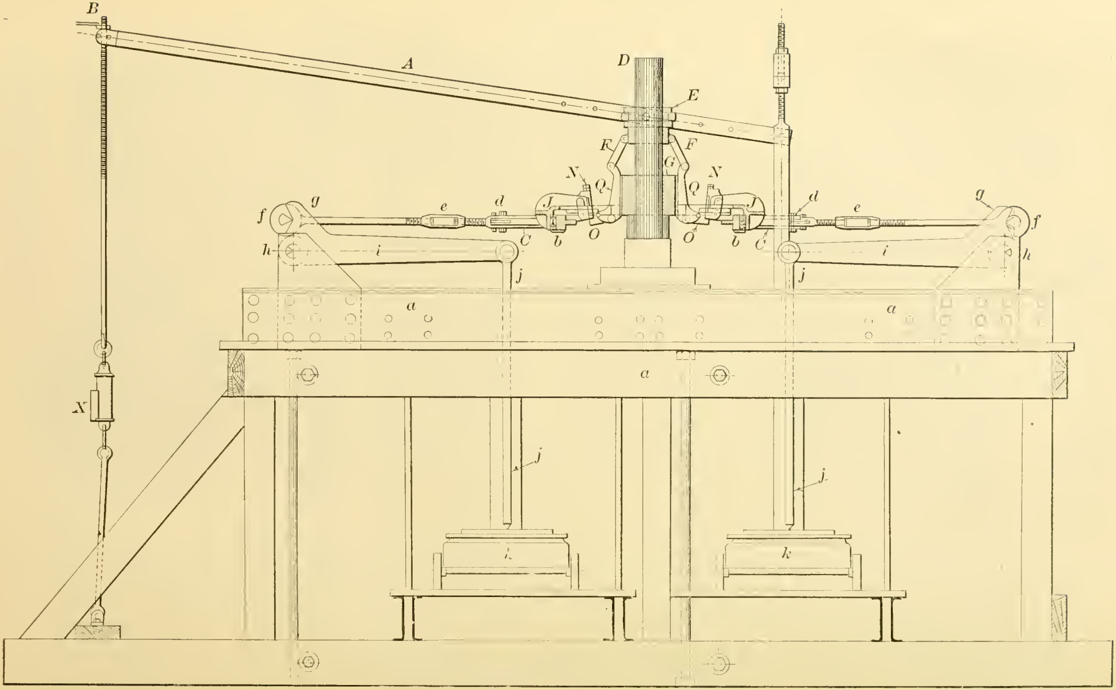

FIG. 3 STATIC CLUTCH-TESTING APPARATUS

less at a time, and the tests made, then another turn, and so on. When the shifter lever A was thrown in by hand power, a man applied his muscular effort to the spring balance X on the end of the lever: when it was thrown in by screw power, the tail-nut B was rotated. The spring balance had a maximum indicator besides the usual one. The motions of the cone E of the different couplings tested varied from 4 in. to $4\frac{1}{2}$ in. Readings of the spring balance were usually taken for each $\frac{1}{4}$-in. or $\frac{1}{2}$-in. motion of the cone.

FIRST SERIES OF TESTS

12 These were made to determine the forces required to throw in the shifter lever at different speeds, when the clutch was in motion and when the clutch was at rest, and before and after the load had caused the clutch to slip on the ring.

13 Tests G, H, I, and M were made on the dynamic clutch-testing machine. The forces required to throw in the shifter lever by screw power and by hand power when the shafts were at rest were first determined, the machine then started up, and the brake tightened until the clutch-coupling slipped on its ring. The brake was then loosened and another test made with the result that less power was transmitted. The wedge nuts were then tightened and the forces required to throw in the shifter lever were measured one or more times and the test continued, as given in Tables 1 and 1-A. In Test M, Table 1-A, readings of the forces required to throw in the shifter lever were taken both when the shafts were at rest and when they were in motion. The shifter lever was thrown in several times and the power determined for a fixed setting of the brake nuts. These were then tightened, and another set of four or more readings taken of the force required to throw in the shifter lever by hand power when the shaft was in motion.

14 With the wedge nuts screwed up two and one-half turns it required a maximum of 70 lb. to throw in the shifter lever by screw power. Immediately thereafter it required maxima of 55 lb. on the first trial, 45 lb. on the second trial, and 43 lb. on the third trial, to throw in the shifter lever by a steady pull by hand power. This shows that the force required to throw in the shifter lever by hand power was much less than by screw power. While this was partly due to the friction of rest being greater than the friction of motion, it was also partly due to the various parts of the clutch adjusting themselves to the conditions after one or two engagements of the

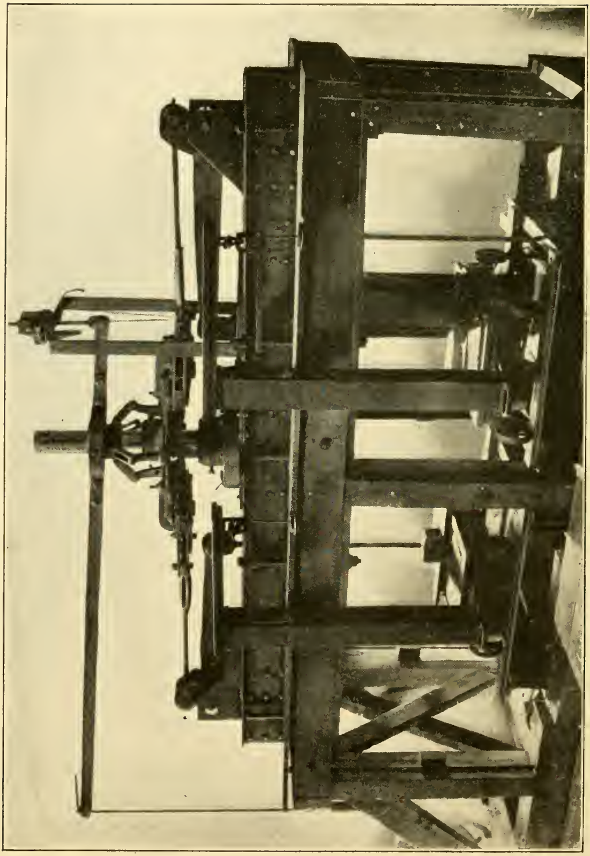

Fig. 4. General View of the Static Clutch-Testing Apparatus

shoes with the ring. This has been frequently noted in practice in the shop.

15 With the same adjustment of the wedges, the clutch slipped when transmitting 84.6, 71.1, and 65.0 h.p., on the first, second, and third sets of trials. This reduction in the brake load shows the effect of wear of the clutch shoes due to the slipping on the ring. This was also indicated by the fact that it required a maximum of only 31 lb. to throw in the shifter lever by hand power after the test.

TABLE 1 FORCES REQUIRED TO THROW IN SHIFTER-LEVER AND HORSE-POWER TRANSMITTED

DYNAMIC CLUTCH-TESTING MACHINE

Wedges Set Up Turns	Distance From Start	Max. Force Required to Throw in Lever with Shaft at Rest. By			Corresponding Axial Pressure. Shaft at Rest. By		Gradually Applied Loads		
		Screw Power	Hand Power	Ratio	Screw Power	Hand Power	Net Brake Load	Rev. per Min.	Brake Horse-Power
Tests G. 24-in., Four-Arm, Solid Clutch-Coupling.									
1.5	2.75	56			277		581	96	63.9
							497	96	54.6
							471	96	51.8
2.5			119			588			
			94			464			
			75			371			
3.0			92			454			
			75			371			
3.5			114			563			
			92			454			
			92			454			
3.5	2.5	103	91	0.883	509	450	1185	92	124.8
		87[1]			430[1]				
Tests H. 24-in., Two-Arm, Solid Clutch-Coupling.									
3.5	2.5	45			222		471	96	51.8
							491	96	54.0
							486	95	52.9
4.0	1.875	114			563				
	2.25	111			548		735	95	79.9
		80[1]			395[1]				

[1] After test and after slipping.

TABLE 1—Continued

Wedges Set up Turns	Distance From Start	Max. Force Required to Throw in Lever with Shaft at Rest. By			Corresponding Axial Pressure. Shaft at Rest. By		Gradually Applied Loads		
		Screw Power	Hand Power	Ratio	Screw Power	Hand Power	Net Brake Load	Rev. per Min.	Brake Horse Power
		Tests I. 24-in., Four-Arm, Split Clutch-Coupling.							
2.5	2.5	70	55	0.79	346	272	...	...	...
...	...	...	45	0.64	...	222	...	...	...
...	...	...	43	0.61	...	212	739	100	84.6
...	...	...	...	...	...	...	621	100	71.1
...	...	...	...	...	...	...	568	100	65.0
...	...	...	31[2]	0.44[2]	...	153[2]	...	...	...
3.5	...	85	65	0.76	420	321	...	...	...
...	...	...	67	0.788	...	331	915	96	100.6
...	...	...	55	0.646	...	272	...	...	...
...	...	...	53	0.623	...	362	...	...	...
4.5	2.25	133	99	0.74	657	489	...	...	...
...	...	...	100	0.75	...	494	1216	94	130.9
4.5	2.00	179	139	0.78	884	689	...	...	...
...	...	...	119	0.67	...	588	...	...	...
...	...	...	119	0.67	...	588	...	...	...
...	...	...	117	0.65	...	578	1371	93	146.0

[2] After test and after slipping. Reduction in b.h.p. shows effect of wear of shoes.

16 After two more sets of trials with tighter adjustments of the wedges, 130.9 h.p. was transmitted at 94 r.p.m.

17 With the wedge nuts screwed up four and one-half turns, it required a maximum of 179 lb. to throw in the shifter lever by screw power, and of 119 lb. to throw it in by a steady pull by hand, corresponding to 884 lb. and 588 lb. respectively, of axial thrust. Under these conditions, when transmitting 146 h.p. at 93 r.p.m., the split clutch broke. This is 77.7 per cent of the breaking load carried by the four-arm solid clutch.

18 From Tests G and I, Table 1, it will be seen that the force required to throw the shifter lever in by a steady pull by hand power, the first time, varied from a minimum of 66.5 per cent to a maximum of 88.3 per cent, averaging about 76.8 per cent of the force required to throw in the shifter lever by screw power; and that the force required to throw in the shifter lever by hand power, after the test,

TABLE 1-A FORCES REQUIRED TO THROW IN SHIFTER-LEVER AND PICKUP LOAD

Wedges Set Up Turns	Max. Force Required to Throw in Shifter-Lever. Shaft at Rest: Screw Power	Shaft at Rest: Hand Power	Shaft in Motion: Hand Power	Ratio	Number of Trials Averaged.	Corresponding Axial Pressure. Shaft at Rest: Screw Power	Shaft at Rest: Hand Power	Shaft in Motion: Hand Power	Pick-up Loads: Actual Net Brake Load	Estimated rev. per Min.	Equivalent Brake Horse-Power
Tests M., 24-in. Four-Arm, Solid Clutch-Coupling.											
2.0	67	......	......	......	1	331	......	......	......	......	......
......	......	61	......	0.91	3	......	301	......	......	......	......
......	......	......	58	0.87	5	......	......	258	94	102	11.0
......	......	......	44	0.67	4	......	......	217	206	100	23.6
3.0	......	124	......	......	4	......	612	......	......	......	......
......	......	......	93	......	5	......	......	459	......	......	......
......	......	......	86	......	4	......	......	425	......	......	......
......	......	......	69	......	4	......	......	341	543	96	59.7
4.0	......	140	......	......	1	......	692	......	......	......	......
......	......	125	......	......	6	......	617	......	......	......	......
......	......	......	115	......	4	......	......	568	......	......	......
......	......	......	105	......	5	......	......	519	501	96	55.1

varied from 44.3 per cent to 64.6 per cent, averaging 54.5 per cent of the force required to throw in the shifter lever by screw power before the test. From Tests I, the ratio of the forces required to throw in the shifter lever by hand power, before and after the tests, varied from 31/45 = 68.8 per cent to 54/66 = 81.8 per cent. It is to be noted that when the four-arm solid clutch broke, when transmitting 187.8 h.p., its wedges had been adjusted so that it required a maximum of 114 lb. to throw in the shifter lever by screw power, corresponding to a maximum of 563 lb. axial thrust. With the same axial thrust applied, the 24-in. two-arm clutch slipped when transmitting 79.9 h.p., or only 42.5 per cent thereof.

19 Tests L, Table 2, were made on the static clutch-testing apparatus. They give the forces required to throw in the shifter lever by screw power and by hand power. The ratios are higher than those given in Table 1 because there was no intermediate starting up, slipping and wearing of the clutch shoes. The last two tests were made with only one jaw in service, the other being disconnected.

20 From these tests it will be seen that the force required to throw in the shifter lever slowly and steadily by hand power averages on the static apparatus 88 per cent and on the dynamic machine about 79 per cent of that required to throw it in by screw power;

TABLE 2 TESTS L: FORCES REQUIRED TO THROW IN SHIFTER-LEVER, AND PRESSURES EXERTED BY CLUTCH-SHOES ON CLUTCH-RING

TESTS ON STATIC CLUTCH-TESTING APPARATUS. 24-IN., FOUR-ARM, SOLID CLUTCH-COUPLING, USING ONLY TWO OUTER JAWS

Wedges Set Up, Turns	Distance from Start	Max. Force Required to Throw in Shifter-Lever Shaft at Rest by			Corresponding Axial Pressure Shaft at Rest by		Net Platform Scale Readings Corresponding to				Actual Shoe Pressures Corresponding to Maximum Force. Lever Ratio=7					Ratio Column 16 to Column 3
							column 3		max. net		to throw in lever		on shoes		total on shoes	
		Screw Power	Hand Power	Ratio	Screw Power	Hand Power	W	E	W	E	W	E	W	E		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
3	1 5/16	44	....	.....	214	....	150	160	263	271	1050	1120	1841	1897	3738	85
3	1 9/16	44	....	.....	214	....	173	182	....	....	1211	1274	.....	.....	.....	.....
4	1 1/16	59	51	0.86	287	246	179	192	330	339	1253	1344	2310	2373	4683	79
5	13/16	77	68	0.86	374	331	207	225	400	409	1449	1575	2800	2863	5663	74
6	13/16	85	77	0.91	413	374	226	234	417	419	1582	1638	2919	2933	5852	69
6.5	9/16	97	90	0.92	472	435	203	216	453	460	1421	1512	3171	3220	6391	66
7	5/16	134	109	0.81	652	530	227	252	535	544	1589	1764	3745	3808	7553	56
7	9/16	110	100	0.91	535	486	249	261	500	504	1743	1827	3500	3528	7028	64
8	5/16	157	134	0.86	763	652	289	310	594	600	2023	2170	4158	4200	8358	53
Average				0.88	....	....	....	....	....	....	....	....	....	....	....	68
4	13/16	33	29	0.88	160	141	125	out of	277	....	875	.....	1939	.....	.....	.....
6.5	9/16	52	48	0.92	253	233	180	service	394	....	1260	....	2758	.....	.....	.....

Maximum force required to throw in shifter-lever acting on outer jaw of only one arm:

- By screw-power.......... 33 lb.
- By hand-power, steady pull.......... 29 lb.
- By hand-power, rapidly.......... 31 lb.
- By hand-power, more rapidly.......... 37 lb.
- By hand-power, suddenly, or by jerk.......... 55 lb.

that this ratio is reduced to about 0.68 by repeated trials of the mechanism when at rest; that the ratio of the forces required to throw in the shifter lever when the shafts are in motion and are at rest varies from 0.91 to 0.87 according to the number of slippings of the clutch on its ring, and may be reduced even to 0.67 after several slippings.

SECOND SERIES OF TESTS

21 The series was made to determine with different adjustments of the wedges the relation of the forces applied at the end of the shifter lever at different points in its motion and the corresponding axial forces, to the forces caused thereby to be exerted by the clutch shoes upon the ring of the clutch-pulley.

TABLE 3 TESTS L: FORCES REQUIRED TO THROW IN SHIFTER-LEVER AND CORRESPONDING PRESSURES EXERTED ON PLATFORM SCALES

TESTS ON STATIC CLUTCH-TESTING APPARATUS. 24-IN., FOUR-ARM, SOLID CLUTCH-COUPLING, USING ONLY TWO OUTER JAWS

Distance Cone is Moved	Corrected Spring-Balance Readings of Forces Exerted at End of Shifter-Lever	Corresponding Net Platform Scale Readings	
Inches		West	East
$\frac{1}{16}$	18	8	12
$\frac{5}{16}$	43	55	65
$\frac{9}{16}$	53	102	116
$\frac{13}{16}$	57	144	159
$1\frac{1}{16}$	59	179	192*
$1\frac{5}{16}$	58	209	222
$1\frac{9}{16}$	53	235	248
$1\frac{13}{16}$	51	256	269
$2\frac{1}{16}$	48	271	287
$2\frac{5}{16}$	43	290	304
$2\frac{9}{16}$	38	303	314
$2\frac{13}{16}$	33	312	323
$3\frac{1}{16}$	32	318	330
$3\frac{5}{16}$	26	321	335
$3\frac{9}{16}$	23	326	337
$3\frac{13}{16}$	16	328	339
$4\frac{1}{16}$	8	330	339
$4\frac{3}{16}$	0	329	339†

* Maximum Force required to throw in shifter-lever.
† Maximum pressure on shoes.

22 Table 2 gives the results of the tests with the static apparatus. The maximum forces required to throw in the shifter lever by screw power and by hand power, and their ratio, the corresponding axial pressures, the corresponding net platform-scale readings, and the actual shoe-pressure readings for these two maxima, are given. "W" and "E" mean "west" and "east" and refer to the relative positions of the two scales on the left and right-hand sides respectively, as in Fig. 4.

23 Comparing the figures in the last column, which give the ratio of the sum of the maximum actual shoe pressures to the maximum force required to throw in the shifter lever, it is seen that the force ratio varies from 85 for three turns of the wedge nuts to 53 for eight turns of these nuts, with an average of 68. This shows that the efficiency is much greater under the lesser pressures.

24 The two tests at seven turns show the effect of compression in the form of set, not only on the shoes but on the various parts and joints of the clutch.

TABLE 4 TESTS F: FORCES REQUIRED TO THROW IN SHIFTER-LEVER, AND HORSEPOWER TRANSMITTED

TESTS ON DYNAMIC CLUTCH-TESTING MACHINE. 24-IN., FOUR-ARM, SOLID CLUTCH-COUPLING

Wedges Set Up, Turns	Distance From Start	Max. Force Required to Throw in Shifter-Lever. Shaft at Rest. By Screw-Power.	Corresponding Axial Pressure. Shaft at Rest. By Screw-Power.	Gradually Applied Loads.		
				Net Brake Load	Rev. per Min.	Brake Horse-Power
	$2\frac{7}{8}''$	51	252	556	90	57.3
	......	......	......	666	94	71.7
	......	......	......	606	97	67.3
One more turn.........	$2\frac{5}{8}''$	97	479	1112	92	117.1
One more turn.........	$2\frac{5}{8}''$	114	563	1665	94	179.2
				1745	94	187.8
	Equivalent horsepower at 100 r.p.m.				100	199.8

25 The following statements are deduced from the results of this series of tests:

a The average ratio of the maximum forces required to throw in the shifter lever with one and two jaws was 0.55.

b The average ratio of the corresponding forces exerted on the ring with one and two outer jaws, counting the forces exerted by only one jaw in each case, was 0.79.

c The average ratio of the corresponding forces exerted on the ring with one and two outer jaws, counting the forces exerted by both the jaws, was 0.38.

d The average ratio of the maximum forces exerted on the ring with one and two outer jaws, counting the forces exerted by only one jaw in each case, was 0.85.

e The average ratio of the maximum forces exerted on the ring with one and two outer jaws, counting the forces exerted by both the jaws, was 0.42.

f In other words, 55 per cent of the force applied at the shifter lever produced only 38 per cent as much corresponding force exerted on the ring, and only 42 per cent as much of the maximum force exerted on the ring, for one jaw rather than two jaws. This was doubtless due to the inequality of the pressures exerted when only one arm was in use, and shows the desirability of so adjusting the wedges of the opposite arms that the shoes bear equally.

26 Table 3 shows the relation of the motion of the cone to the maximum force required to be applied at the end of the shifter lever and to the forces exerted by the clutch shoes upon the dummy ring-segments in Tests L, and is a fair sample showing that the maximum force exerted on the shifter lever does not produce the maximum force exerted on the clutch shoes.

TABLE 5 TESTS N: FORCES REQUIRED TO THROW IN SHIFTER-LEVER, AND HORSEPOWER TRANSMITTED WITH GRADUALLY APPLIED AND PICKED-UP LOADS

Tests on Dynamic Clutch-Testing Machine. 24-in., Four-Arm, Solid Clutch-Coupling.

Wedges Set Up, Turns	Distance From Start	Maximum Force Required to Throw in Lever. Shaft at Rest. By Screw-Power.	Corresponding Axial Pressure Shaft at Rest. By Screw-Power	Gradually Applied			Suddenly Applied Loads		
				Net Brake Load	Rev. per Min.	Brake Horse-Power	Net Brake Load	Rev. per Min.	Brake Horse Power-
3	2.5	53	263	711	96	78.2	471	96	51.8
3	2.75	43	212[1]						
4	2.25	90	445	1035	92	109.0	471	98	52.9
4	2.5	58	286[1]						
5	2.25	125	617	606	96	66.6	491	98	55.1
				606	96	66.6	561	96	61.7
				746	94	80.5	628	95	68.3
				621	93	66.1	981	91	102.2
							986	91	102.7
Equivalent horsepower at 100 r.p.m.								100	112.8

[1] After slipping three times.

THIRD SERIES OF TESTS

27 The third series of tests was made to determine the frictional resistance between the clutch shoes and the ring of the clutch-coupling in motion and at rest.

28 For these tests, a cast-iron plate, $1\frac{15}{16}$ in. thick, 12 in. wide, and 36 in. long, and maple blocks $\frac{27}{32}$ in. thick, 3 in. wide, and 9 in. long were used. The angles of inclination of the plate at which a block would begin to slide from rest, and at which it would continue to slide after being started into motion, were taken as the angles of friction respectively for the two cases. The horizontal forces required to be exerted in order to start the block from rest, and to continue it in motion when placed on the carefully leveled plate, were taken to be the natural tangents of the angles of friction respectively for the weights carried by the block.

29 The smoothness of finish of the block, the uniformity and trueness of the bearing surface, the deflection of the plate, the cushion of air between the block and the plate, each has its effect on the angle of friction.

30 The number of tests made with flat maple blocks does not warrant the drawing of very positive conclusions, but it would seem that the average frictional resistance under load was greater from rest than the resistance under load in motion, in the proportion of the tangent of 18.5 deg. to the tangent of 13.3 deg., or in the proportion of 0.33 to 0.24.

FOURTH SERIES OF TESTS

31 The next series of tests was to determine the power transmitted for different adjustments of the wedges corresponding to different forces required to throw in the shifter lever, including the maximum power which the clutch-coupling was capable of transmitting, and the maximum power which it was capable of picking up from rest.

32 For these tests, the dynamic clutch-testing machine was used. The wedges were adjusted so that the shoes bore fairly equally. To determine the maximum power which the clutch-coupling was capable of transmitting, the wedge nuts were gradually tightened, and the brake screwed up either until the coupling slipped, in which case the wedge nuts were tightened up further, or else the clutch broke. Table 4 gives the results of this set of tests, from which it will be seen that with a maximum of 114 lb. applied by screw power at the end of the shifter lever, corresponding to an axial thrust of 563 lb., when revolving at 94 r.p.m. under a net brake load of 1745 lb. the clutch transmitted 187.8 h.p., under which condition the clutch slipped, the speed varying from 94 to 98 r.p.m., and both clutch and ring broke. This corresponds to 199.8 b.h.p., or practically to a maximum of 200 b.h.p., for a speed of 100 r.p.m.

33 Table 5 gives the results of the tests with the dynamic clutch-testing machine, of the forces required to throw in the shifter lever, and the horsepowers transmitted with gradually applied and suddenly applied loads. The latter are what are sometimes called pick-up loads. From this table it will be seen that with a net brake load of 986 lb., when running at 91 r.p.m., the clutch picked up 102.7 h.p. and had it started when the clutch broke. It had just previously picked up 102.2 h.p. This corresponds to 112.8 maximum b.h.p. of pick-up load for a speed of 100 r.p.m.

FIFTH SERIES OF TESTS

34 The last series was to determine the relation of the maximum forces applied at the end of the shifter lever and the corresponding axial forces, to the maximum power transmitted by two-arm and four-arm clutches for the same adjustment of the wedges.

35 To perform this test on the clutch which had been tested in the dynamic clutch-testing machine (See Tests H of Table 1), the two opposite pairs of jaws were disengaged by unscrewing their wedge nuts, and retaining the same adjustment on the two other pairs of shoes. It was found that it then required a maximum of 45 lb. to throw the shifter lever in by screw power, and that when revolving at 95 to 96 r.p.m. the clutch slipped at 51.8, 54.0, and 52.9 b.h.p. respectively. When the wedges were tightened up one half turn further, it required a maximum of 114 lb. to throw the shifter lever in by screw power. When running at 95 r.p.m. the clutch slipped when transmitting 79.9 h.p. After the test, it required a maximum of only 80 lb. to throw the shifter lever in by screw power.

36 Comparing the tests of these clutches, with four arms and two arms, the wedge nuts being turned up three and one-half turns in both cases, the horsepowers required to slip the clutch were found to be 124.8 and 52.9 (average of 51.8, 54.0, 52.9). This would seem to show that the two-arm clutch transmitted only 44 per cent as much power as would the same clutch with four arms for the same adjustment of the wedges. As the axial thrusts, however, were in the same proportion, 103 to 45, it would seem as though the horsepowers transmitted were directly proportional to the number of arms, whether two or four, and to the forces required to throw the shifter lever in by screw power, and therefore to the axial thrusts. No tests were made with six-arm clutches.

CONCLUSIONS

37 Applying the deductions of Tests L, Table 2, to Tests F, Table 4, we may say

A That at 100 r.p.m., with the shoes properly burned in and the wedges adjusted so as to give equal pressures between each of the eight shoes and the ring, and with no excessive lost motion between the jaws and their guides in the clutch-arm casting, a 24-in. four-arm solid clutch and ring will probably break:

a When transmitting 200 h.p., if gradually applied.

b When attempting to pick up a load exceeding 110 h.p.

B That to do so will require:

a A maximum force of between 100 lb. and 115 lb., applied at the shifter lever for a leverage of five.

b A maximum axial force or thrust on the collar of between 500 lb. and 600 lb.

c A combined maximum pressure of the eight shoes on the clutch ring of between 7500 lb. and 8000 lb.

d An intensity of pressure of about 50 lb. per sq. in. for each of the twenty square inches of each of the eight shoes of the four-arm clutch.

C That any inequality or lack of evenness and uniformity of the pressures with which opposite shoes bear on the ring, or any lost motion between the various parts, will decrease the breaking strength of the clutch.

D That a 24-in. four-arm split clutch will probably break when transmitting between 140 and 150 b.h.p. at 100 r.p.m., if the force is gradually applied and under proper conditions.

E That the factor of safety of 10, as used by the clutch manufacturer in this case, is quite ample.

AN ELECTRIC GAS METER

By Prof. C. C. Thomas, Published in The Journal for December

The following addition to his paper was given orally by Professor Thomas in presenting it before the Society at the meeting of December and should therefore be considered a part of the paper.—Editor.

THEORY OF THE METER AND METHOD OF OBTAINING STANDARD RESULTS

32 The figures given in paragraphs 14, 15 and 19 can be reduced to standard conditions of temperature and pressure, and the meter readings can be autographically recorded directly in "standard cubic feet" of gas or air. Let

G = cubic feet of gas per hour
E = energy in kilowatts

Then B.t.u. per hr. = 3412 E

T = temperature difference, deg. fahr.
S = specific heat per cu. ft.

Then $G\ S\ T$ = heat energy equivalent to E, or $GST = 3412\ E$. $\frac{GT}{E} = \frac{3412}{S}$ = a constant K which depends upon the specific heat of the gas.

33 Since the temperature difference T is kept constant, it follows that $\frac{K}{T}$ is constant. Let $\frac{K}{T} = C$. Then $G = \frac{KE}{T} = CE$.

34 It is now proposed to show by reference to the gas and the air curves in Fig. 10, that if the specific heat of gas made under given conditions be calculated from the customary chemical analysis and the specific heat of the constituents, then this specific heat may be used for determining the constant C. From the gas curve (Fig. 10), which was made with illuminating gas at an average temperature of

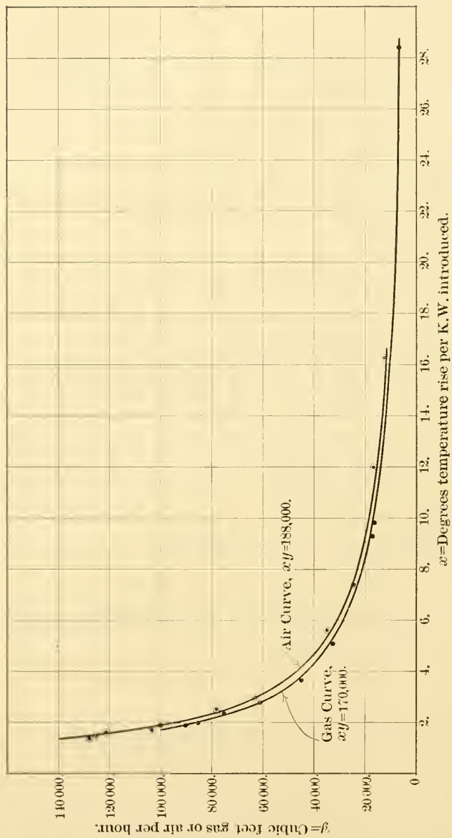

Fig. 10 Showing Degrees Temperature Rise per kw. for Different Rates of Flow of Gas and Air

59 deg. fahr., and under an average absolute pressure of 6 in. water and 29.8 in. mercury,

$$K = 170{,}000 = \frac{3412}{S}$$

35 Therefore for the condition of the gas when the tests were made the specific heat per cubic foot $= S \frac{3412}{170{,}000} = 0.0201$. If this be reduced to standard conditions of 32 deg. fahr. and 29.9 in. mercury, then $S = 0.021$, which is to be compared with the calculated specific heat (Par. 14), giving $S = 0.0211$. If the standard conditions are taken as 62 deg. fahr. and 29.9 in. mercury, the specific heat becomes 0.0198, and the constant becomes

$$K = \frac{3412}{0.0198} = 172{,}500, \text{ nearly}$$

If the temperature difference is kept constant at 5 deg. fahr., then $\frac{K}{T} = \frac{172{,}500}{5} = 3450 = C$, or $G = 3450\ E$.

36 The cross-section paper on the recording wattmeter is ruled so that 3450 E is read directly, instead of the watts E. The record is thus read directly in cubic feet of gas. The regular records of chemical analysis of the gas should be referred to from time to time in order to ascertain what percentage variation takes place in specific heat. It appears, as stated previously, that the elements which vary during the operation of a gas plant are not those whose variation would produce serious variation in specific heat. The variation that does take place is apparently well within the limits of accuracy practicable, or generally considered necessary in the operation of gas plants. By taking frequent chemical analyses the error can be reduced so as to be quite negligible.

37 The conditions during the air tests were as follows: barometer, 29.75; pressure, 6.5 in. water; average temperature of air as measured in the wet meter, 60 deg. fahr. From the air curve obtained under these conditions (Fig. 10)

$$K = 188{,}000, \text{ and } S = \frac{3412}{188{,}000} = 0.0181$$

38 Reducing this to standard conditions of 32 deg. and 29.9 in. mercury, $S = 0.0191$. This is to be compared with the accepted specific heat of air under these conditions, or 0.0192 B.t.u. per cu. ft.

This provides perhaps the best evidence that could be obtained, as to the accuracy of these tests, since the specific heat of air is well known at the conditions under which the tests were made. A more commonly familiar figure for specific heat of air is obtained by multiplying 0.0192 by the number of cubic feet of air per pound under the above conditions, or 12.38. The result is 0.2377 B.t.u. per lb. per deg. and this is to be compared with 0.0191 × 12.38 as given by the meter, or 0.2365.

39 The constant K for air at 32 deg. and 29.9 in. is therefore

$$\frac{3412}{0.0191} = 178{,}630$$

and reducing this to 62 deg. instead of 32 deg.

$$K = \left(1 \times \frac{30}{493}\right) \times 178{,}630 = 189{,}500 \text{ nearly}$$

If $T = 5$ deg., $\frac{K}{T} = 3790.$

40 The error involved in calling this constant 3800 is less than ½ of 1 per cent and well within the limits of accuracy possible under the circumstances. The standard cubic feet of air passing the meter are therefore $G = 3800\ E$, and the autographic records are arranged to read accordingly, in standard cubic feet of air per hour.

41 The development of a new device requires consideration of a large number of questions arising out of the conditions of service proposed. The question of specific heat has been considered in the preceding paragraphs. The degree of success which has been attained with this meter in accurately measuring specific heat is due principally to an extensive experience in this particular class of work, which has served to point out the way to make an electrical heater in which heat losses are negligibly small. The arrangement of the meter is such that the heat given off can go into the gas only, and it necessarily all goes into the gas, with the exception of a negligibly small loss which it is not worth while to minimize further. That the gas receives all the heat, excepting this negligibly small loss, is true whether or not the heating material has collected deposit of some kind. So long as the gas can get through the heater, its temperature is raised proportionately to the heat supplied.

42 The question of the presence of a small amount of water vapor, as part of the gas, has so far not introduced any complications. It

is conceivable that if the gas carried a large percentage of water the operation of the meter would be interfered with,—but so would the operation of a gas engine or a burner. The meter can apparently measure accurately any gas that can be used by a gas engine. The absence of moving parts in the meter gives it an advantage over the engine, and dust can be to a considerable extent deposited before entrance of the gas to the meter. The heating element and thermometers can be cleaned by dipping in gasolene, without damaging them.

43 Meters at present under construction are being made with the axis of the cylinder vertical, with a view to greater convenience of access and in making connections.

44 The first large meter of this type to be installed was put in the works of the Milwaukee Gas Light Company, and the writer is indebted to the officials of that company for their coöperation in making extensive tests during the work of development.

45 Referring to Par. 16, for gas or air under the conditions existing during the tests, of approximately 60 deg. fahr., 29.8 in. mercury and 6 in. water pressure, the correction for water vapor introduces a change in the results of less than one-half of one per cent, and was therefore omitted. At other pressures and temperatures the correction for water vapor can be easily made by reference to the charts commonly used in gas works. An interesting confirmation of the statement in Par. 16 appeared during the tests, in that the most minute addition of electrical energy caused an immediate rise of temperature of the gas or air. This was repeatedly tried with great care, and always with the same result.

THE TRAINING OF MEN—A NECESSARY PART OF A MODERN FACTORY SYSTEM

By Magnus W. Alexander, Lynn, Mass.
Member of the Society.

Emerging from the depression of the last two years, American industries are once more entering upon an era of prosperity, which in the natural course of events should surpass in magnitude and intensity anything yet seen in the industrial world. One obstruction alone lies in the path of this unrivaled future: lack of men to do the work is the fact that confronts keen observers of the situation. There is no lack of enterprise in the country; money for sound business undertakings is plentiful; and the consuming capacity at home and abroad is increasing from year to year. But are we in a position to utilize these factors to the fullest extent?

2 Only a few years ago the cry for efficient men in all branches of industrial activity was universal and insistent, and manufacturers everywhere complained of their inability to man their establishments properly. Skilled mechanics were at a premium; capable industrial foremen and superintendents were painfully scarce; while positions of leadership calling for men of education, experience, and breadth of view could be filled only with difficulty.

3 The industrial depression of 1907–1908 naturally relieved the embarrassment; but even then skilled mechanics and efficient foremen could not be secured in adequate numbers. The last few months have already clearly demonstrated that the acuteness of the situation has returned, and that this condition will be accentuated as time goes on. Should we, then, not profit by the lessons of the past and cast about for an adequate remedy? Now is the time to analyze the situation, and, in the light of our experience, work out a comprehensive policy which will enable us to cope with the exigencies as they arise. This is a matter which concerns every manufacturer, large and small; it is as much a problem of business sagacity as of immediate necessity.

4 In December 1906, I had the privilege of presenting to The American Society of Mechanical Engineers my ideas concerning the train-

ing of young men for positions as skilled mechanics and foremen, and of showing how this scheme had been put into practical operation through the apprenticeship system of the General Electric Company at West Lynn, Mass. In the meantime this system has been materially extended so as to provide adequately for the boy with a grammar school, a high school, or an engineering college education. New lines of factory work have been included, and cognizance has been taken of the necessity for training machine specialists. The educational scheme of the Lynn Works, therefore, presents in its present scope a comprehensive policy.

5 The underlying thought of all this training is the belief that skill will demonstrate its full potential value only as it is supported by intelligence. Each course of training, except in the case of machine specialists, includes, therefore, distinctive educational work, and the scope of each course is based on the previous education of the individual. There are, of course, young men of pronounced native ability, who, no doubt, would prove to be efficient in training courses from which the above educational requirement excludes them, but to deal with these exceptions would complicate the process of selection and the system of training. In the training courses for trade apprentices alone, which are ordinarily open to grammar school graduates only, boys with an incomplete grammar school education, who can pass a satisfactory examination, may be admitted; in all other courses rigidity of requirements is necessarily maintained.

6 In the training leading to positions as machine specialists, such as shaper, lathe and boring mill hands, milling machine operatives, etc., no provision has yet been made for educational advancement as distinctive from training for skill. This can be effected at any time, however, without undue expenditure.

7 The company recognizes the existence of workingmen who are in the class of unskilled labor from lack of opportunity or of foresight or due to other circumstances not under their control and for the same general reasons remain in such service. Many, of course, by disposition and general makeup, are bound to find their livelihood in such unskilled labor, while on the other hand, many can be trained in a comparatively short time to semi-skilled and skilled special work. Such training will increase their economic value and their contentment and add materially to the productive efficiency of the factory.

8 In pursuance of this policy a systematic effort is made to select from among the unskilled workers men of from 20 to 35 years of age, who give fair promise of success as machine specialists. Some of

these men are now receiving instruction in lathe work, others in shaper or boring mill, or planer or milling machine work. This training lasts from three to four months, depending on individual capacity, and the men receive during that time an hourly rate which gives them a living wage. A capable instructor makes the selection, assigns the men to the various factory departments where machines and work are available, and supervises their training.

9 These men are, of course, under the foremen in whose department they are working for the time being, but the instructor, who is a very capable skilled mechanic, having had charge of men for many years, visits them almost daily and sees that they receive work of an instructive character and of advancing difficulty, as far as this can be done without undue interference with the productive requirements of the factory. When the instructor is satisfied with a man's capability of handling his machine and of turning out a fair amount of work, he assigns him permanently to a foreman who requires such service. The machine specialist then takes his place as a regular workman and receives regular day or piece work compensation. The same man, however, may apply again to the instructor for special training on some other machine; thus gradually fitting himself for a position as all-around machinist and tool-maker, with correspondingly higher compensation.

10 An arrangement of this kind entails no material hardship on anyone, gives many men an opportunity to rise to a higher plane of efficiency, automatically supplies the factory with capable machine specialists, and tends to attract to the factory men of ambition and stamina. This work might be further extended by giving to those who cannot sacrifice the temporary reduction of wages, an opportunity to receive their training during evening hours and on Saturday afternoons. This problem was outlined in my paper, A Plan to Provide for a Supply of Skilled Workmen (Transactions, vol. 28, p. 439).

TRAINING OF MECHANICS, FOREMEN, DESIGNERS, ETC.

11 Far more comprehensive in scope, and covering a longer period of time, must of course be the training of those who are to take positions as highly skilled mechanics and foremen, designers and engineers, superintendents and managers. The industries themselves must furnish this training, inasmuch as our school systems do not provide for it today, and very likely in the future will be able only to approach the full requirements. Mental training closely correlated with prac-

tical instruction may be gained by putting both under the sole charge of the factory management; or smaller factories may combine for joint classroom instruction; or the theoretical instruction may be delegated entirely to public school authorities, who could provide special classes for instruction alternate days or weeks. All three schemes are in operation today, and either will prove effective if properly managed, and if selected with reference to local conditions, size of factory and available personnel.

12 A bare outline of the system established by the General Electric Company, at West Lynn, which was fully treated in my former paper, may be of interest as showing how it has developed in the last three years, during which time about one hundred apprentices have graduated from the course.

REGULAR APPRENTICE TRAINING

13 Boys of at least 15 years of age, who have had a grammar school education or its equivalent, may be admitted on completion of a two months' trial period, to the regular apprentice course. It is largely contended by manufacturers that boys under 16 are not fit for trade training. A normally bright boy, however, unless he goes to high school, will usually be obliged to seek employment at 15, and it is better for him to be put immediately under systematic trade instruction. Naturally, the work at the beginning must be suited to the boy's immature physical as well as mental development, and boys lacking in physical strength will be accepted neither at 15 nor at 16 years of age.

14 The training for future tool and die makers, instrument makers and pattern makers, lasts four years, while iron, steel and brass molders, blacksmith and steam-fitter apprentices, who should be somewhat older and stronger, receive three years of training. The two months of trial are included in this period. Apprentices receive compensation, even during the trial period, at the rate of 8 cents per hour for the first six months, 10 cents for the second six months, 12 cents for the second year, 14 cents for the third year, and 16½ cents for the fourth year. Molder, blacksmith and steam-fitter apprentices, on the other hand, receive 10 and 12 cents per hour respectively for the first and second six months' periods, 14 cents for the second year, and 16½ cents for the third year. In either case satisfactory completion of the course entitles the graduate to a Certificate of Apprenticeship and a cash bonus of $100. The normal number of working hours is 55 per week.

15 The average compensation paid to graduated apprentices is $2.75 per day, although some are started at $3 a day immediately upon graduation. The significance of these figures is more fully appreciated when it is borne in mind that the young man of 21 years receiving such pay is only just beginning his life's work, with a solid preparation for marked future advancement.

16 All apprentices are obliged to spend from an hour and a half to two hours in the classrooms every day except Saturday, except during part of July and August, when instructors and apprentices may take their vacations. Classes meet during regular working hours, usually at the beginning or end of the half-day periods. Full compensation is paid during classroom hours. Retention on the course and the payment of the bonus are dependent on satisfactory work in the classroom as well as in the shop, and the standing in both is stated on the Certificate of Apprenticeship.

17 The classroom instruction is based on a grammar school education, and includes arithmetic, algebra, geometry and trigonometry, physics as it concerns simple machines, power transmission, strength of materials, machine design, magnetism and electricity, mechanical drawing, and jig and fixture design. For pattern-maker and molder apprentices an extended course in mechanical drawing is substituted for tool design. This instruction is practical, with constant reference to the work of the apprentices and to the usual factory problems, the aim being, above all else, to develop the ability to reason, and to foster a pride of vocation.

18 In no way is this stimulated more than by the daily practical talks of the superintendent of apprentices, who carries, so to speak, the factory into the classroom. The many answers offered by the apprentices to such a question as, "Why does a one-inch drill cut a larger hole in cast iron than in steel?" reveal their mental capacity and mechanical understanding and give the superintendent a splendid opportunity for driving home practical truths. The superintendent continues this kind of instruction in the apprentice training room. If he notices, for instance, that an apprentice uses an improperly ground tool, he calls a number of the boys to the blackboard and explains clearly by means of sketches what is wrong about the tool and how it should be sharpened.

THE APPRENTICE TRAINING ROOM

19 The training room is a special department for apprentices, a trade school in the factory, with this distinction, however, that all

work is commercial work selected solely for its instructive character. It had its inception in the belief that the apprentice should receive his initial training under the most favorable conditions and expert supervision. The very fact of this work being a part of the commercial output of the factory automatically insures a high standard of quality and quantity, and eliminates the false notions of these values usually found in purely educational trade schools. As a matter of record, the work of the apprentice is of a very high standard. Moreover, on work of a repetition character, the apprentices attain a speed of from two-thirds to three-quarters of that of the average workman. and a quality of work fully equal to the average; while on work generally classed as tool work, the apprentices very closely approach and sometimes even equal the work of the skilled journeyman.

20 The reports of the general inspection department show that rejected motor shafts, for instance, average only 2 per cent. although the permissible limits for the journal and other parts of the shaft are usually not more than 0.0005 in., and in any event not more than 0.001 in. Other work requiring accuracy to micrometer measurements is equally creditable to the apprentice training. Wherever possible, jigs made by the apprentices are not allowed to leave the training room unless the accuracy of the work has been proved by drilling or machining a part for which the jig was made. Several molds for various materials have been recently finished in the apprentice training room and the accuracy of the work proved not only by the pieces molded, but also by the fact that the parts of the various molds could be accurately assembled in the different permissible combinations.

21 Training rooms have been established for tool-maker and pattern-maker apprentices, occupying departments of about 15,000 sq. ft., and 4000 sq. ft. respectively. No training room has yet been organized for molder apprentices, of whom there are only a few, this part of the system being not yet very far developed. The training rooms are in charge of expert mechanics who act as assistant foremen to the superintendent of apprentices. One assistant takes care of about 25 apprentices in the pattern training room, and four assistants look after the business conduct of the machinist training room, with the instruction of about 130 apprentices. The small number of instructors and supervisors is explained by the arrangement under which the apprentices themselves, at various stages, act as instructors to those less advanced. In this way, not only is the instruction carried on with economy, but latent ability for executive

work is developed and the apprentices are taught self-reliance much more quickly than if their every step was directed by journeyman instructors; the aim being to train skilled and intelligent mechanics, as well as to develop on this basis industrial foremen.

22 It is indicative of the individual instruction afforded, that not infrequently a boy teacher has served a shorter period of apprenticeship than the pupil he instructs. No course has been laid out for the practical work; each apprentice being advanced as fast as is consistent with his individual capacity. He must have a fair understanding of his machine and be able to produce his work with commercial accuracy and a fair degree of speed before he can be advanced.

23 The company believes that inasmuch as it pays good apprentice wages and offers excellent training and educational advancement, it is justified in expecting a high standard of workmanship and of deportment. Accordingly, a rigid weeding-out process takes place throughout the course; more than 50 per cent of those serving the trial period are dropped at the end of two months and quite a few are discharged even after having signed the apprentice agreement. At first, a provision was made to send the apprentices to different departments in the factory, after about a year in the training room; later on, the time in the training room was extended to two years and the tendency now is to increase it to about three years before giving the apprentice a change to acquire additional experience. The advantages of this arrangement lie not only in the extended systematic training of the apprentices, but also in their better general supervision during the most impressionable period of their lives. At times, of course, apprentices in all stages of training are loaned to factory departments for a few days or weeks; on the other hand, some of those who have already progressed into the factory are brought back into the training room, if the quantity or quality of their work, or their deportment, necessitates such disciplinary measures.

24 At the present time there are over 200 trade apprentices at the Lynn Works, while 101 have already graduated. Of these 63 are now in the employ of the company, 8 serving as assistant foremen, 5 as inspectors and 12 as tool draftsmen, while the remainder work as skilled journeymen. Many of the latter, no doubt, will rise to positions of added responsibility during the next few years. The point is made clear to all apprentices, however, that a position as foreman or superintendent should not be the sole aim except for those with predominant executive ability. The percentage of graduates remaining with the company—in many respects a measure of the success of

the scheme—varies, but it has never dropped below 55 and at times has been over 80.

DRAFTSMAN APPRENTICES

25 No less encouraging are the results achieved with draftsman apprentices. Training for positions as draftsmen and designers is limited to young men with a complete high school education who pass examinations in algebra, plane geometry and elementary physics. It has been found necessary to introduce this examination on account of the great divergence in the curricula of high schools and the great difference in scholarships among graduates. Accepted applicants must serve a two months' trial period satisfactorily before being indentured for an apprenticeship of three years at 10 and 12 cents per hour respectively for the first and second six-month periods, fifteen cents per hour for the second year, and twenty cents for the third year. They receive then a cash bonus of $75 and a Certificate of Apprenticeship which states their efficiency in practical and in theoretical work.

26 Draftsman apprentices are obliged to attend classroom exercises about an hour and a half every day, except on Saturday and during part of July and August; and a considerable amount of home study is required. The educational work consists of advanced algebra, descriptive and analytic geometry, plane trigonometry, advanced physics, inorganic chemistry, strength of materials and machine design. Instruction is for the most part of college rank, and college text books are used entirely, but again the closest correlation with the practical work in the shop and drawing office is maintained.

27 Examinations are held three times a year and failure to pass in all subjects with at least 70 per cent necessitates the repetition of a fourteen weeks' period. A second failure in the same subjects, or repeated failures in different grades, result in the discontinuance of the whole course. This does not necessarily mean that the delinquents must leave the company, for under certain conditions they are permitted to continue on the shop apprentice course under a four years' agreement. A few have already made this adjustment.

28 Draftsman apprentices receive machine shop training during the first year and a half, and drafting instruction during the remainder of the three years' course. The machine shop work is given principally in the apprentice training room on account of special facilities for this instruction; a part of the time, however, is devoted to repair

work on machinery, and to tool work. The object is to give the future draftsman and designer an adequate insight into practical work so that he may appreciate in his designs the possibilities and limitations of the shop, and may, moreover, bear in mind the use of jigs and fixtures for economic manufacture on a large scale. The shop work, finally, inculcates in the young man an appreciation of the value of time and money such as he would not easily acquire without this training.

29 The work in the drawing office begins with a brief period of tracing, for the purpose of teaching the use of instruments, neatness, and the general arrangement of shop drawings; it continues on detail drafting and finishes with layout and design work. The high quality of the work of the apprentice is the natural consequence of the careful selection of applicants and the enforcement of a high standard of practical and educational achievement. Most of the young men are indeed a credit to the system.

30 The course for draftsman apprentices was originated about six years ago, but on a less ambitious plane. Grammar school graduates were then admitted for a four years' training, and no particular stress was laid on educational instruction. It was soon found, however, that in this way good tracers and detail draftsmen could be developed, but not high-grade draftsmen and designers. About four years ago a high school education was made an entrance condition, and a course of three years was offered. Soon after, class room instruction was added, extending but slightly beyond a review of the high school program. The apprentices who had been admitted under the less exacting requirements naturally fell behind and had to drop out, and the standard of the educational and drafting work was then gradually raised. Thirty-two apprentices have been graduated under these conditions, most of whom have become competent draftsmen, while a few have started on promising careers as designers.

31 Still the company was not satisfied with the scope of the course. It was recognized that the general standing of a draftsman and the standard of his work had everywhere deteriorated during the last decade, largely on account of the great influx of superficially prepared draftsmen. To develop draftsmen and designers of pronounced capacity and intelligence would dignify the work and regain full recognition of its potential importance. Moreover, the graduates of the machinist apprentice course proved to be capable of developing into competent tool and mechanial draftsmen, so that the demand for high-grade, intelligent designers became the more

pertinent. The final change in the course was therefore made, about a year ago, calling for an entrance examination, for educational work of collegiate grade, and for the extended training in shop work.

32 Ten draftsman apprentices are finishing their apprenticeship under the less exacting conditions, while twenty-four are receiving their training in the new course, and their progress augurs well for their future. In fact the training under the prevailing rigid system is expected to prove so effective that the privilege of a one year's post-graduate course in the various testing departments will be extended to all draftsman apprentices whose shop and office work has been very satisfactory and who have a standing of at least 85 per cent in all theoretical studies. These young men will then be eligible for important positions in engineering or commercial organizations.

33 Two other opportunities for systematic training have recently been opened to high school graduates, one for the preparation of testers and erectors of machinery, the other leading to a business career in a manufacturing establishment. These courses were instituted only within the last few months, and the results can only be foreshadowed.

TESTER AND ERECTOR APPRENTICES

34 Tester apprentices must pass an examination the same as draftsman apprentices, and the length of the two courses and the rates of compensation are identical. The practical work consists of about six months of testing motors or transformers, followed by about nine months of assembling and winding, the remaining year and nine months being devoted to a training in the various testing departments for meters and instruments, arc lamps, rectifiers, railway motors, and special electrical machinery, also turbines and turbo-generators. This work will be carefully supervised by a competent instructor, who will arrange for transfers from one class of work to another, and who will constantly keep the tester apprentices up to the required standard.

BUSINESS APPRENTICES

35 Business apprentices are recruited from high school graduates who have a leaning towards business activity, but not sufficiently high scholarship to pass the entrance examination and continue the educational work prescribed for the drafting and testing courses. These apprentices enter upon a two years' course at a compensation of

12 cents per hour for the first year and 15 cents for the second year, with a cash bonus of $50 at the successful termination of the course. They begin with six months of general stockkeeping, which acquaints them with the principal materials used in the factory, and leads to an appreciation of the value of these materials. Then follows a nine months' training on the writing of material lists and the compiling of stock reports. In this way the apprentices learn to read drawings and to make up lists of the kinds and amount of materials required for the production of one or several machines or machine parts delineated on drawings. They learn, furthermore. to calculate the losses that result from the cutting off of bars and the punching of various shaped parts. All this leads to accuracy and develops an interest in the value of stock which will show in the stockroom work of a more independent character which occupies most of the remaining nine months. These apprentices will also be given a training in shop clerical work, and this will be supplemented by instruction in arithmetic and geometry, the reading of drawings, and simple bookkeeping. This course has been instituted because the great value of proper stock keeping and factory accounting is recognized.

STUDENT COURSES

36 So far the plan outlined has dealt with methods of increasing the industrial efficiency of workmen and of preparing boys with a grammar or high school education for the trades and for semi-professional service. The company also seeks to provide, for young men of engineering collegiate training, an entrance into the industrial field which will lead to positions of scientific importance and administrative responsibility.

37 In common with other manufacturers the General Electric Company established many years ago, a "student course" providing for a two years' experience in the various testing departments of the Works. The young men were usually assigned to a testing department for a certain time, and were then more or less automatically transferred from one department to another until they had covered the whole course within the specified time. They very often did not take the work seriously enough, and in any event their chief aim was to get a general knowledge of as large a field as possible, rather than to acquire thoroughness in each specific field.

38 The company endeavored to eliminate these defects by organizing some three years ago a supervisory committee. This committee

met frequently with the students, and examined each one once or twice a year, in order to test his theoretical and applied technical knowledge, and his alertness for taking full advantage of the educational opportunities offered. In this way the committee was enabled to weed out some who showed no capacity for future responsible work, and to modify the course in each case to fit the individual student, and lead him into the field of his greatest probable usefulness. This arrangement unquestionably improved the general standing of the student training.

39 The real value of the committee's work, however, has been in the close contact of the members of the committee with several hundred students, and the opportunity to study carefully and specifically the bearing of the student training upon the work of the graduates in various positions inside and outside the factory organization. The committee soon recognized that while the training above described was, in general, a good preparation for those who elect positions in the selling organization, it did not give the right kind of experience to those who are to become designing, manufacturing and administrative engineers. This latter group needs a far more comprehensive knowledge of mechanical processes and a better understanding of the economic forces at work in a modern industrial establishment than can be acquired in the testing departments. With this in mind, the student course was put on a new basis a year and a half ago, and the work so far accomplished bears out the correctness of the premises.

40 In the present form the student course is divided into two parts, the so-called engineering and the commercial course. Admittance to either is dependent on a complete engineering college education, and almost invariably applicants must appear personally before the committee. The courses last two years and the compensation has been set at 20 cents per hour ($11.00 per week) for the first year, 22½ cents per hour ($12.37) and 25 cents per hour ($13.75) respectively for the two halves of the second year. Without written agreement it is mutually understood that the student will give to the company two years of faithful service, and that the company, on the other hand, reserves the right to terminate the work of any student who at any time proves that he is not above the average either in capacity and special fitness or in good intentions. Aside from the direct advantage of such a rigid arrangement, is the added result of attracting to the course, as has already been demonstrated, high-grade young men, some even with one or two years of practical experience after graduation from college, who aspire to positions of prominence and realize

the value of a stiff training course with correspondingly good prospects. Even in busy times, when college graduates are in demand everywhere, young men with inherent capabilities will gravitate toward the Lynn course or any other course of equally high order.

41 Weekly evening lectures have been arranged, which all students are expected to attend, when the engineers and foremen of the company, as well as heads of the business departments, informally address the young men and stimulate a free and frank discussion of the subject under consideration. These lectures cover the principal materials of construction, important manufacturing processes, and the various lines of apparatus manufactured by the company. Occasionally talks dealing with business methods are interspersed. The complete program includes lectures on: (1) Iron foundry practice; (2) Steel foundry practice; (3) Pattern making; (4) Alloys and their properties; (5) Stockroom methods; (6) Forging; (7) Hardening; (8) Welding; (9) Factory cost keeping; (10) Tool steels; (11) Shapes of cutting tools; (12) Cutting speeds and feeds; (13) Piece-work rating; (14) Fibrous insulating materials; (15) Oils and varnishes; (16) Porcelain and molded compounds; (17) Shop bookkeeping; (18) Wires and cables; (19) Selection of materials in reference to design; (20) Drawing office methods; (21) Principal machine tools; (22) Care of and repairs to machinery; (23) Interchangeability of parts; (24) The essentials of production; (25) Punch press operation; (26) Die making; (27) Automatic machine processes; (28) Distribution of labor charges; (29) Requirements of accuracy in machine work; (30) Arc lamps; (31) Incandescent lamps; (32) Mercury lamps and rectifiers; (33) Lighting systems; (34) Factory building construction; (35) D. C. and A. C. motors; (36) Electrical features of motors; (37) Mechanical features of motors; (38) Motor drive of machine tools; (39) Labor report and pay roll; (40) Fan motors; (41) Industrial motor applications; (42) Railway motors; (43) Gears and pinions; (44) Avoidable factory losses; (45) Meters and instruments; (46) Standardization of instruments; (47) Sheet iron for electrical machinery; (48) Annealing of iron; (49) Transformers; (50) Testing of electrical machinery; (51) Shipping and receiving methods; (52) Steam turbines; (53) Valve gears and governors; (54) Buckets and bucket wheels; (55) Turbo Generators; (56) Turbine testing; (57) Wage payments; (58) Centrifugal compressors; (59) Gas motors; (60) The labor problem; (61) The reading of technical magazines; (62) Salesmanship; (63) Factory management.

42 Lectures are illustrated, by samples of materials and machines,

pictures, drawings and charts. They put the students in possession of up-to-date, practical information which they are not able to get from books or from outside sources. Lecturers and students alike have expressed their enjoyment of these evenings, which inculcate a certain class spirit which results in added ambition, increased loyalty to the employer and a broader conception of the work. This class spirit is discouraged, on the other hand, during the daily work, that the students may never forget that they must earn, as well as learn, in the service of their employer.

COMMERCIAL STUDENT COURSE

43 Commercial students spend about 2 months on meter and instrument testing, 2½ months on arc lamp testing and repairing, 1½ months on transformer winding and assembling, 4 months on transformer and rectifier testing, 2½ months on stationary and railway motor winding and assembling, 6 months on stationary and railway motor testing, and 5½ months on turbine testing or on other special assignments. They are stimulated to keep in touch with the latest engineering developments by carefully reading the technical magazines, and are shown the value of following up the advertisements in them as one means of getting acquainted with the general features of apparatus manufactured by competitors. Finally, the students are assisted in visiting power stations and installations, where they may see apparatus of various manufacturers and learn to observe keenly the essential points of operation.

44 Engineering students, on the other hand, receive most of their training in the machine shops, winding departments and drawing office, while the latter part of the course is devoted to testing, or to production, cost or other business activities as the capacity and inclination of the individual student may make advisable. These students are usually started on machine work in the apprentice training room, where they can receive instruction under the most favorable conditions for the first month or two. During this time, also, they can be closely watched, and here the first process of elimination takes place. In the next eight or nine months, students are assigned to various departments of the factory, in some of which they are put entirely on production work, in order that they may come under the influence of the intensity of production and may learn the possibilities of output on various machines, and in others they get experience in tool-making and repairs to machinery. Students who show an inclination toward heavy work are usually assigned to departments

in which the machining of turbines, street-car motors, and large motors in general, is done. Students inclined toward light work are, on the other hand, transferred to machine and tool-making departments in the arc lamp, meter and instrument or fan motor building. Some of the students spend a month or two in winding and insulating departments, again with particular reference to their future specialty.

45 For the following ten months, approximately, students are assigned to the drawing office, where they work first on detail drawings and then on assembly and layout work. Part of this time is devoted to tool designing, when students learn to design a drill jig or milling fixture or similar auxiliary apparatus for economic wholesale manufacture. The advantages of the drafting experience are obvious, especially for those who wish to become designing and manufacturing engineers. Inability to read drawings quickly, with an eye that sees the delineations grow into shape and form an achievement which can usually be gained only through a somewhat extended drafting experience, prevents many college-bred junior engineers from occupying positions of responsibiltiy in designing and manufacturing work. Drawing is the language of the engineer; it is equally useful to the one who supervises draftsmen and designers, or who interprets shop drawings to the mechanic and the foreman, and to the one who wishes to sell a piece of apparatus, when, by means of sketches he can illustrate the advantageous points of manufacture.

46 The remaining four or six months of the course are devoted to specific work leading to some definite occupation after graduation from the course. Thus, if the committee and the student agree that his future work should lie along manufacturing lines, he may act for a month or two as assistant to a department foreman, and acquire additional specialized shop experience. Another student, better fitted for scientific research or for general mathematical work, may receive a few months' experience on testing, especially of experimental apparatus, and may temporarily be assigned to an engineering department. A student who has shown particular aptitude for commercial work may be given some production and cost-accounting experience, while the future salesman is given an opportunity to spend the remainder of his course in various testing departments. A strong point is made of studying the development of each student, week by week, in order to train him along lines of his greatest capacity.

47 This purpose, as well as the desire to assist every student in the best way possible, and at the same time to exact from him a full

measure of service, has led to the appointment of a special instructor whose function it is to keep in almost daily touch with every student throughout the plant. The instructor endeavors to make the foremen of the departments, to whom students are assigned, sympathetic with the whole educational scheme, and to secure for the student work that will be especially helpful to him; he sees to it that every student works at the highest point of efficiency, and whenever he finds him doing his work in anything but the most approved fashion, or using wrongly sharpened tools, or fine feeds where coarse feeds are the proper thing, he explains and insists on remedial action. He, furthermore, tries to inculcate in the student a proper conception of his work, and to make him feel that while he must at all times give service, some one who is sympathetic stands ready to assist him.

48 The instructor makes a written report of the work of each student once a week, and presents it at the weekly meeting of the committee. The committee discusses every student in the light of the report, lays out his course for four weeks or four months ahead, as the case may permit, and talks personally to those of whom the instructor is not able to report favorably. An admonition is usually considered equivalent to placing the student on a few weeks' probation, with the understanding that he will be dropped without hesitation if at the end of the probation period a decided improvement cannot be reported. The committee, furthermore, interviews new applicants, and selects those for the engineering or commercial course.

49 A competent instructor with testing experience will soon be appointed to follow the commercial students through their course, unless the commercial course is abandoned on the theory that students with a training such as the engineering course offers will be better salesmen than if they had testing experience alone.

50 All in all, it would seem that the student training has been laid out on a broad basis, with due regard to the interests of the student as well as those of the company; and it is fair to expect that this training will develop a body of theoretically and practically educated young men, who, on account of their knowledge, their broad conception of things, and their sympathetic outlook, are in line for positions of the highest order either with the company or with other concerns.

51 A definite policy, a sympathetic following up of the students, insistence upon a high standard of work, and a sympathetic oversight of the students by a committee of competent men, are the distinguishing features of the Lynn student courses.

52 The educational policy of the Lynn Works provides systematic training suitable to all classes of people. The unskilled worker without particular education receives a training adequate to his immediate needs; the grammar school boy is initiated into the trades on the basis of a four years' course with educational instruction of a high school character; the high school graduate is trained for semi-professional service of a technical or business nature, on the basis of a three years' course with educational instruction of collegiate grade; and the college graduate is prepared for professional service of the highest order, on the basis of a two years' training of which the educational instruction assumes the character of a post-graduate college course. Obviously, there are other ways of obtaining these results. Coöperative efforts between the engineering college and the factory, for instance, may be substituted for college instruction, followed hy practical training through a student course. (See address before the American Institute of Electrical Engineers, June 1908, A Method of Training Engineers.) Educationally, psychologically and economically, the scheme is sound.

53 There are three main problems that enter into production,—the machine problem, the material problem, and the man problem. It is clear that the man problem is the most difficult of solution but also the most important in competitive activity. It must be approached in the same scientific manner and with the same painstaking concentration of effort that is today applied to the other two problems. The training of men must be the key-note of our industrial expansion. At least in the larger industrial establishments, this calls for a new type of engineer who might appropriately be known as the economic engineer.

DISCUSSION

THE HIGH-PRESSURE FIRE-SERVICE PUMPS OF MANHATTAN BOROUGH, CITY OF NEW YORK

By Prof. R. C. Carpenter, Published in the Journal for September

ABSTRACT OF PAPER

This paper describes the high-pressure pumping systems installed for fire service in the city of New York and gives the results of tests of the pumping machinery. There are two pumping stations for the system located in different parts of the city, deriving their supply from the Croton system, although sea water can be used in an emergency. There are five pumping units in each station consisting of Allis-Chalmers five-stage centrifugal pumps driven by induction motors. The pumps each have a capacity of 3000 gal. per min. and a delivery pressure of 300 lb. per sq. in. The distribution system covers a large section of the city between Chambers and Twenty-third Streets and is designed for the high pressure that must be met in service. In the tests the quantity of water discharged was measured by venturi meter. Tests were made of the pumps when running together and of certain of the pumps running singly under different discharge pressures. The efficiency of the pump tested singly in one of the stations under normal conditions varied from 70 to 77 per cent, and of the pump tested in the other station, under the same conditions, from 76 to 79 per cent. The pumps were put to a crucial test on January 7, 8 and 9, 1909, when brought into service for five simultaneous fires. Seven pumps were operated, delivering 35,500 gal. per min. against an average pressure of 225 lb. at the pumps and 205 lb. at the hydrants. The total pumpage was 14,095,000 gal., and the current used 81,450 kw-hr., costing $1222.

DISCUSSION AT NEW YORK

Prof. George F. Sever.[1] The electrical features of this installation are of much interest but the reasons for selecting that system which is now in operation should be given. In the discussion of this problem both alternating and direct-current power were considered for the operation of the motor-driven pumps, and alternating-current power was decided upon. The reasons for such selection I have noted herewith:

[1] Professor of Electrical Engineering, Columbia University.

a Absolute simplicity, that being the key-note of the electrical end of this power installation.

b The absence of all commutating apparatus and brushes.

c Induction motors provide very quick starting when it is necessary to operate the station on a fire signal.

d There is less expense for copper in the distribution system to insure continuity of service.

e The induction motor is a less expensive apparatus than the direct-current motor.

f With the induction motor there are absolutely no exposed live circuits in the station, as there might be with a direct-current apparatus. The final decision was for 3-phase service at 6600 volts and 25 cycles. It was decided that it would not be desirable to establish a power house to be operated by the city because it would be a municipal plant.

2 In order to insure continuity of service there is brought to each pumping station an independent feeder from each of the two Waterside stations of the New York Edison Company. There is also brought to each pumping station an independent feeder from the nearest substation of the New York Edison Company, as follows: to the Gansevoort Street station two feeders from the Horatio Street substation, and to the Oliver Street station two feeders from the Duane Street station of the company. Hence there are really four independent sources of power supply for each pumping station, assuring practically no possibility of shutdown.

3 The contract for electric power for the Manhattan station was let to the New York Edison Company. This contract provides for two payments, the first for a reservation of 3250 kw. capacity, of generating, distributing and controlling apparatus, available at either pumping station at an instant's notice, or practically without any notice at all. Thus four pumps can be thrown on with absolutely no notice to the New York Edison Company that they are to be used. For that reservation, and care and maintenance of the whole distributing system, the city pays about $63,000 per year, and the city also pays one and one-half cents per kw-hr. for all high-tension power used in each station.

4 There is also another interesting stipulation in the contract, which may be of interest to the engineers as it provides for the protection of the city. This stipulation is as follows: "If the contractor, under the terms of this contract, shall fail to maintain and deliver

a continuous and uninterrupted supply of electric power when required, the contractors shall and will pay to the city the sum of five hundred dollars per minute for each minute's interruption or delay of electric power supply after the power has been interrupted or delayed for three consecutive minutes." So, if they cannot deliver power after an interruption of three minutes, immediately a charge of $500 per min. is imposed and is deducted from the bills which the New York Edison Company renders.

5 The operation of both these stations is extremely simple. The handle of the oil switch is turned, throwing the 6600 volts directly on the stator of the motor. By turning a hand wheel, the motor is brought up to speed in less than 33 sec., and in starting the current is not supposed to exceed 150 per cent of the full-load current, which is 64 amperes. As far as I have observed the operation of the station, there has been absolutely no trouble from the electrical end, no trouble with the feeder system, and none with the motors, and I think the City of New York has two plants which will give them for many years to come absolutely no trouble whatsoever.

Wm. M. White. The paper deals with questions in which I am directly interested. The methods employed in making the tests were probably the best that could have been selected. There is probably no more accurate method of determining the quantity of water delivered by a pump than by the venturi meter, especially when in the hands of an expert who is familiar with its workings. The venturi meter, as Professor Carpenter says, has been used for a number of years; it has been tested in various ways and proved to give accurate results. The power delivered to the pumps can be most carefully obtained by electrical instruments.

2 The writer accepts without question the various efficiencies obtained and presented by the author, who states, calling attention to the variation in efficiencies obtained, that the individual observations do not agree as closely as he would like. I do not think Professor Carpenter should offer any apology as the results seem to agree very closely, and certainly are as accurate as are generally obtained on work of this kind. The efficiencies obtained on these pumps, though not the highest that have been obtained, are as high as is usual for similar conditions of head, capacity and speed. The designers of the pumps deserve credit for the performance shown by the pumps.

3 I am at a loss to find a reason for the variation in efficiencies of the pumps, as mentioned in Par. 65, where it is stated that individual

pumps delivering water into a main singly show greater efficiency than the same pumps delivering together into a single main. I assume, of course, that the variation in efficiency refers to the pumps when they are delivering exactly the same quantity against the same head at the same speed, whether working singly or in parallel. In the normal operation of pumps, it would be a fact that when one pump was operating from a suction main to a discharge main, the efficiency of that pump would be different from what it would be when working with another pump from the same suction main and discharging into the same discharge main, because the two pumps would usually be working against a higher head than when a pump was working singly. The increased head on the pumps would mean a decrease of capacity, and the increase of power demanded by two motors instead of one would mean a slight increase in line loss, which would again slightly decrease the speed and slightly change the conditions of operation for two pumps over that which would exist when one pump only was in operation. Of course, under these conditions, the two pumps would show different efficiencies, because the efficiency curve of a pump varies as its capacity and head.

4 I do not believe, however, that this is the condition to which Professor Carpenter refers. I assume that he has corrected for this difference, and has obtained from two pumps working in parallel the same capacities, heads and speeds as though one pump were in operation, and that under this latter condition he finds the difference in efficiency in the two pumps. If this be a fact, it is the most important point brought out from a designer's point of view.

5 I am at this time attempting to duplicate the conditions, to see whether the efficiencies are different under the same conditions of capacity, head and speed, as mentioned by Professor Carpenter.

George L. Fowler. A number of years ago I was associated with Joseph Edwards, who at that time had the contract for excavating the ship channel in New York Harbor, probably one of the first, if not the first, very large hydraulic engineering projects successfully accomplished by the contractor and to the satisfaction of the Government.

2 The ship channel leading from the Narrows down to Sandy Hook and out to sea, is about 15 miles long, and runs almost due south first, turning to nearly due east before reaching Sandy Hook, and passing through Gedney Channel to the sea. Cutting across it is

the Swash Channel, not used by any deep-draft boats. When the work was undertaken New York Harbor was shoal at two points on the Gedney Channel and the ship channel, where the water depth was a little less than 24 ft. The Government had a survey made and an estimate of costs based on material actually removed by the ordinary methods of dredging. Through the open space from Sandy Hook to Coney Island the whole lower bay is subject to all the winds coming in from the Atlantic on the east and across Raritan Bay, so that the water is nearly always rough. Two contractors had attempted the work by ordinary bucket dredging and both had failed.

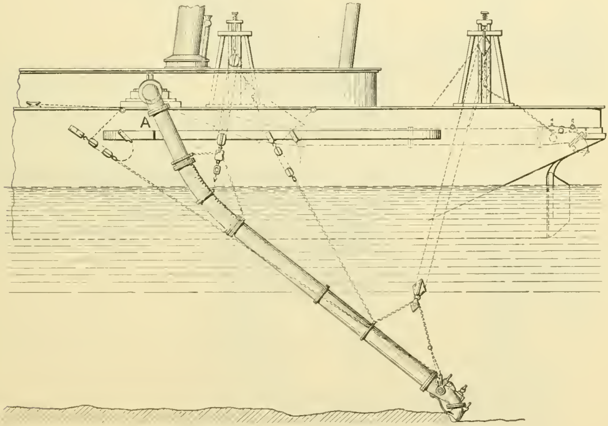

Fig. 1 Hydraulic Dredger for Deepening Ship Channels

3 In the ship channel the material was sand and sedimentary clay, lying over hard sand; in the Gedney Channel it was gravel, shell and sand, for two feet overlying hard shingle. Hydraulic dredging was specially suited for this kind of work, and many kinds of material were removed from the channel besides the ordinary silt.

4 Three sea-going vessels were built for this work by the Joseph Edwards Company: the Reliance, the Advance, and the Mt. Waldo. Fig. 1 shows the general arrangement of the ships. At *A* is the long drag aft, where the pipe goes into the vessel and where the pumps are located, each driven by a 192-h.p. engine at 178 r.p.m. The suction and delivery pipes were 15 in. in diameter, with a shell of 40 in. The

pumps delivered 10,000 gal. per min. at a velocity of 1100 ft. The efficiency was thus between 65 and 70 per cent, although in later tests made by the Government, when nothing but water passed through the pipes, the efficiency rose to as high as 80 per cent.

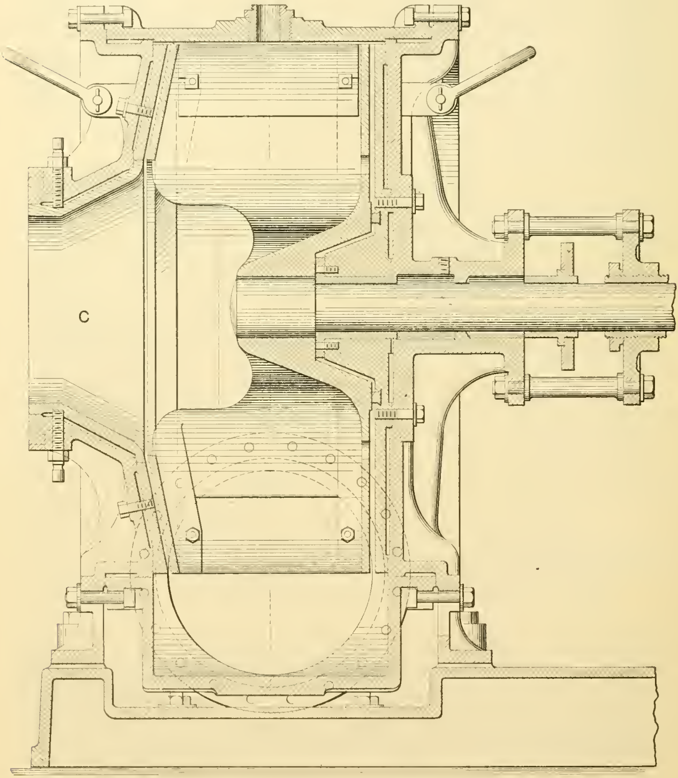

Fig. 2 Sectional View of Centrifugal Pump for Dredging

5 The shoe used is a hook that drags along the bottom, chains being fastened to the vessel for this purpose. The vessel never

stopped from morning to night, simply running out to sea, dumping, and coming back again to work.

6 At the point *L*, Fig. 3, was the heavy shoe that served to dig into the mud and gravel. At *O* was a butterfly valve, kept open all the time to admit water above the drag to mix with the material raised. At the bottom *K* was another valve which could be opened in an emergency, in case not enough water was admitted at *O*.

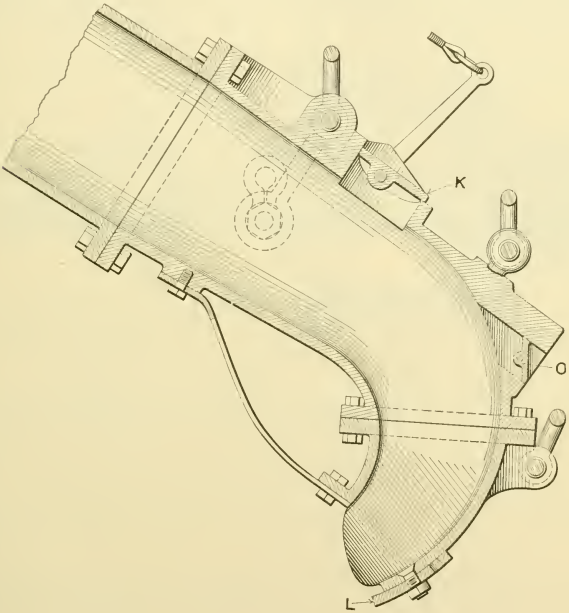

Fig. 3 Detail of End of Suction Line

7 The pump itself was of a plain centrifugal type, 40 in. in diameter, with vanes cut away at the center, as shown in Fig. 3. Because of this arrangement, the material would come in at *C* and out of the vanes at the discharge, without damaging the pump when heavy substances were drawn in. The three vanes were made with wings

bolted on, and accessible from both sides. The thrust was taken up by the bearing at *T*, the nuts marked *m* being screwed into a head carried by the bars *O*, bringing the thrust plates at the point *i*. The reason for threading the nut *m* was to adjust it to the vanes in proper relative position to the sides of the pump. That is a simple construction maintained ever since, with the exception that ball bearings are now used.

8 Although the pumps were originally intended to take water and other loose material, such as sand and gravel, they proved capable of lifting practically anything that came in their way. The three following specimens are interesting as showing the pumps' lifting power:

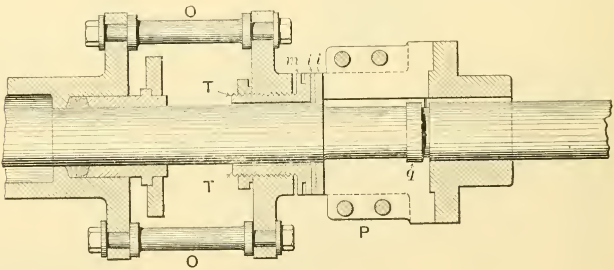

Fig. 4 Detail of Thrust Bearing of Pump

A piece of shaft weighing 70 lb. raised and passed by a 15-in. dredging pump; improvement of New York Harbor, Steamer Reliance.

A piece of tree root raised and passed by a 12-in. pump from 14 ft. of water at Miami, Fla.; Florida East Coast Railway Company improvements.

A piece of pig iron measuring $11\frac{1}{2}$ in. by $4\frac{3}{4}$ in. by $3\frac{1}{4}$ in. and weighing 35 lb. raised and passed by an 8-in. special cataract wrecking-pump from 15 ft. of water from the wreck of a canal boat sunk at Puas Dock, Yonkers, N. Y., by the Baxter Wrecking Company, New York.

9 For hydraulic dredging, the Government pays by the scow load and gets what is excavated. In ordinary hydraulic dredging, like that in the ship channel, about 15 per cent of the pump discharge was solid matter. About 40 per cent in excess of the amount deposited

in the bins went overboard with the overflow, and was carried out to the flats at the sides by the cross currents, which also carried the loose material stirred up by the drag. The result was that the Government obtained an excavation about 70 per cent in excess of what would have been obtained had all of the material removed from the bottom been caught in the bins. This, of course, greatly reduced the actual cost of the excavation. For example: the last contract made on the ship channel was at the rate of 16⅞ cents per yard, while with the allowance indicated, above the actual cost per yard—channel measurement—it was about 11 cents.

10 As for the time of loading, some records indicate that this ship, 157 ft. long and with a capacity of 650 cu. yd., was loaded in 48 min.; there are also records of its being loaded at the rate of 16 cu. yd. per min., of solid matter placed in the bins; and records of its taking out to sea nearly 4000 cu. yd. per day. The vessel was worked in all kinds of weather, even when tackles had to be used to board her; and yet the ship was taking her load steadily. Except in the case of an actual breakdown the work could be carried on for 16 hr. per day.

John H. Norris. In a pumping plant of the character described, this type of equipment seems in the present state of the art the most suitable that could have been selected. I would like, in this connection, to call attention to another type of installation for service of this kind, though not on so large a scale, which appeals to me as being more desirable than the electric driven centrifugal pumping plant taking its power from the public utilities company.

2 At Coney Island was installed the first plant operated by the City of New York for fire protection by means of water delivered into mains under high pressure, with the idea of taking care of a restricted area where there was great danger from fire.

3 This plant consists of three 150-h.p. three-cylinder, vertical gas engines direct-connected to triplex pumps, each unit capable of pumping 1500 gal. per min. against a pressure of 150 lb. These engines take their fuel from the mains of the local gas company and can be arranged if necessary to run on gasolene. They are installed in a building on city property and are arranged to take their water supply from the city mains or from Coney Island Creek, within 50 ft. of the pumping station. The engines are started with compressed air, and the three units can be started up in less than three minutes. On every occasion they have been found ready for service whenever

the demand was made upon them. The cost of this pumping station was as follows:

Building	$10,000	
Equipment	37,000	
	———	$47,000
The annual operating expenses are:		
Labor		$13,140.00
Supplies and Repairs		897.27
Fuel		150.00

4 By comparing the foregoing figures it will be evident that for service smaller than is required in the City of New York, the gas-engine-operated triplex pump gives an economical equipment that can be allowed to stand idle for any length of time and yet be ready for instant service.

5 New York City pays the New York Edison Company an annual charge of $90,000 for the privilege of calling for sufficient current to operate the equipment at any time. This item capitalized at 5 per cent would pay for a good-sized gas-engine plant.

6 The following data were taken from the capacity tests of the Coney Island units:

Duration of test	14	hr.
Average piston speed of pump	90.3	ft. per. min.
Total head pumped against	156.5	lb.
Average pump horsepower for each unit	142.2	h.p.
Average gas consumed per hour for the 3 units	8914.0	ft.
Average gallons per minute	4512.0	
Slip of pump	3.45	per cent
Average efficiency of pumps	82.00	per cent

J. R. Bibbins. Although Professor Carpenter's paper deals primarily with multistage pumps, I wish to direct attention to the question of motive power, upon which the success or failure of the system practically depends. We have seen excellent examples of two systems diametrically opposed in regard to power supply—the electrical and the gas-driven system. Under certain conditions, both are extremely serviceable. The first high-pressure installation on a large scale, in this country, was the gas-driven system at Philadelphia. Although I have not had an opportunity to follow the results of that station for the past two or three years, the results obtained and published for

the first year or so showed that such a system of gas-driven pumps merits every consideration.

2 First as to the security of power supply: In Philadelphia the Delaware Avenue station receives its gas supply directly from a 24-in. trunk main running between two very large gas holders, located in different parts of the city. Roughly, the pipe line measures four miles in length, its capacity constituting a considerable reserve in itself, if both the holders were unavailable. There is no intermediary apparatus whatever between the pipe line and the engine; that is the plant may draw directly on these two large holders of several million cubic feet capacity. This constitutes a very safe and reliable source of motive power which can hardly be paralleled except, perhaps, by the situation in the New York electric service, where there are so many stations to draw from.

3 In this connection, I would like to ask whether it is at present possible to utilize the storage battery capacity in the various sub-stations for reserve service at the high-pressure pumping station? It is stated that the storage batteries are available for reserve in emergencies, such as discontinuance of the main high-tension current supply. I am under the impression that an inverted rotary requires a direct-driven exciter to maintain a definite frequency and prevent racing. Without special controlling apparatus, this inversion would be impossible in the ordinary sub-station equipment. Possibly special provision has been made in the New York systems, in which case, the security of power supply is certainly beyond criticism. In other words, would it be possible to invert the synchronous converters on short notice?

4 Second, quick starting: It seems to be a fact that a large part of the minimum time required for the starting of a fire-service station is consumed in the operation of the motor-driven by-pass valves. In Philadelphia these valves are operated from an independent supply, as in New York, and at least fifteen seconds are required to close them; whereas the engines are brought up to speed within half a minute from the time the signal is given, the remaining time being usually consumed in closing this motor-driven valve.

5 The various tests of the Philadelphia plant showed that each of the units could be readily put on the line in well under one minute. It is an interesting fact that the original underwriters' tests specified the time limit as twelve minutes for the starting of the first three units, whereas the whole station can be started in that time, and has been started in seven minutes.

6 During the 36 days of preliminary service trials of the Philadelphia station, out of one hundred alarms given, only four misses were made in getting any of the eleven units started. In not a single instance has the station, as a whole, failed to respond to the service, at least during the period over which my observation extended. This has been accomplished with the regular operating force of three men.

7 Third, in regard to the cost of service at Philadelphia: The only data on a large fire available, are those of the fire in the Coates Publishing House, which lasted about nineteen hours. The average cost for pumping was about six cents per thousand gallons, including gas, wages and supplies. The cost of the large East Side service, cited in the paper, is about nine cents for power alone, and I think this does not include the readiness-to-serve factor. On the other hand, it is patent that the cost of service in either the gas or the electrical station is relatively unimportant. The main desideratum is reliability.

8 Finally, I desire to advance an argument for the development of a new type of pump unit, namely, a high-speed gas-driven centrifugal pump. Some time ago, in connection with water-works service, I found great difficulty, even with the present high-speed single-acting gas engine, in matching engine speeds with those required in centrifugal pump work. However, for the pressure necessary in water-works practice, about 125 lb., one or two sizes of engines were found to be directly applicable to multistage pumps, with fair proportion of parts and good efficiencies. It seems possible to adopt a modified type of gas engine which would permit the direct connection mentioned.

9 This modification would naturally follow along lines of short stroke and high piston speeds with perhaps four cylinders. The engines at Philadelphia were designed with a piston speed of but 730 ft. per min. with a 22-in. stroke. This might be increased to 1000 ft. per min. without exceeding present-day limits, especially for units designed for occasional service. Such a unit would find immediate application in many industries and would combine the high economy of the gas engine with the simplicity of the centrifugal pump. The efficiencies shown by Professor Carpenter place the centrifugal pump in a position of closest competition with reciprocating pumping units.

J. J. Brown. I recently made a series of tests on three 6-in., 8-stage centrifugal pumps, each designed for 1000 gal. per min. and 560 lb. pressure at 1200 r.p.m. One of these pumps gave an efficiency from wire to water of 71 per cent, or a pump efficiency of 76 per cent. I

regret that Professor Carpenter did not give the results of his tests on the New York fire-service pumps at lower capacities. All of the tests were made at capacities considerably in excess of that for which the pumps were designed and they apparently show their best efficiency at approximately 25 per cent over the normal rating. This increased efficiency at excess capacity seems to be apparent in several recent tests made on high-lift centrifugal pumps. The 8-stage machines previously referred to give their best efficiency at 1300 gal., or about 30 per cent over rating.

2 Mr. White has raised a question as to the difference in efficiency between the New York fire-service pumps working in multiple and as separate units. I think this is occasioned by the variation in capacity of the pumps when working together on a common suction and discharge line. I have found it rather difficult to balance two centrifugal pumps on a common discharge, and pitot tube tests indicate in almost every case a considerable difference between the amounts of water handled by the individual units under these conditions.

3 I have in mind one installation on fire service, where the pumps were called upon to deliver against the maximum pressure for which they were designed and it was only with considerable difficulty that we were able to cut in additional units. I think that if venturi meters or pitot tubes had been placed on the discharge of each of the five pumps when they were working in multiple, a difference in capacity of the several units would have been shown, which would account for the difference in efficiency observed when the pumps were working individually and not in multiple.

George A. Orrok. At the time of the award of contract for these fire pumps, the New York Edison Company was obtaining proposals for centrifugal feed pumps—a somewhat similar service—and eight 1000-gal. 300-lb. pressure fire-stage pumps were purchased. There was no attempt to obtain a high guarantee for efficiency, but the builders did state that under the above conditions an efficiency of 65 to 68 per cent would be obtained. These pumps were of the Jager type and under test showed an efficiency of about 68 per cent.

2 Fig. 5 shows that the high-pressure fire-service pumps are of the Kugel-Gelpke type and should be a trifle more efficient because of smaller friction and leakage. Seventy-one per cent seemed a very high efficiency and many doubts were expressed regarding the fulfillment of the guarantees. The extreme figure of 79 per cent obtained is probably the result of careful design and extra good shop

work and I believe has not been excelled. That this figure came as a surprise may be explained by the fact that most centrifugal pumps are stock pumps and not specially designed for the work they have to do. Pump manufacturers have been more concerned in getting a line of patterns that will suit standard conditions than in developing a line of pumps and system of patterns capable of doing the best work.

3 As a centrifugal pump is a reversed mixed-flow or Francis reaction turbine, similar care in design and construction would probably give efficiencies similar to those of the best makes of reaction turbines, which approximate 90 per cent.

Frederick Ray. The difference in efficiency of the units operated individually from that obtained when several were operated in parallel might be due to the different rates of flow through the venturi meters under the two conditions. With one pump operating, this flow would be low and the mercury column reading would be but slightly over an inch, so that with a given error of observation the percentage of error would be much greater than with two or three pumps discharging through the same meter.

2 Professor Carpenter here replying that the pipe connecting the two meters was open all the time, Mr. Ray continuing said:

3 This would equalize the flow in the meters when the whole station was running, so that the mercury column reading would be about 6¼ times the reading with one pump. It has not been my experience that parallel operation of a number of pumps has any tendency to decrease or otherwise change the efficiency obtained when operated individually. The efficiency should be the same, and in this case, as the pressures were taken at each pump, any losses in the piping system due to parallel operation would be external to the gages and would not show in the calculations. If the pressure had been taken at the discharge of the whole system, losses in the piping would affect the results.

4 Many pumps are running under similar conditions, at the efficiencies given. I have myself obtained efficiencies of 79 or 80 per cent and higher, but I do not rely as much on them as on some a little lower. I am now testing a 6-in., 2-stage underwriter pump, having a normal capacity of 500 gal. per min. against 100 lb. pressure, which has developed a maximum efficiency of 73 per cent.

5 I think the centrifugal pump is the ideal one for fire service, not only on account of its simplicity and reliability, but also on account of its characteristic increase in capacity as the pressure is

reduced. Thus, the 500-gal. underwriter pump referred to will discharge 870 gal. per min. at 60 lb., or enough for four streams at this pressure. It will give three streams at 90 lb., two streams at 110 lb. and one at 117 lb.—all at constant speed without any regulation whatever.

6 The City of Toronto has recently issued specifications for centrifugal pumps for their general municipal water supply, among which are several fire pumps capable of discharging against 300 lb. pressure. These pumps, however, are to be equipped with variable-speed induction motors, the pressure regulation being obtained by speed variation. This is superior to throttling regulation from the standpoint of current economy and in the case of the New York installation a considerable saving could be made by this means, as most of the fires can be handled with 200 lb. pressure or less.

H. Y. Haden. A somewhat unusual result is obtained from this type of pump, for as the total head continues to increase beyond a certain point, the capacity falls off, with the result that the capacity curve, as given in Fig. 7, shows a backward tendency. It will be interesting to get the explanation of this.

2 There is unquestionably a large field in fire protection for steam-turbine-driven centrifugal pumps, and it is to be hoped that the Fire Underwriters will officially accept this type of fire protection unit. I believe that a properly designed centrifugal pump, for high speeds and of few stages, can be used to great advantage when direct-connected to high-speed turbines.

Thomas J. Gannon.[1] It was decided to use electricity as power for the pumping stations, because the first cost of installation and the yearly cost of operation and maintenance and fixed charges were estimated to be lower, taking into account the intermittent service. The construction and operation of a steam plant were entirely out of consideration and the choice lay between gas-engine-driven and electric-driven pumps receiving power from outside sources.

2 It was estimated that gas operation of plants equal in capacity to the present electrically driven plants, would involve a fixed charge of $50,000 a year, in addition to the cost of the gas actually consumed. The question as to who should build and maintain

[1] Engineer, Dept. Water Supply, Electricity and Gas, Manhattan Borough, New York.

the necessary large gas mains, the cost of which would approximate a million dollars, was not definitely settled. That the cost of a gas-engine-driven pumping plant would have been approximately double, both for machinery, building and area of land to be purchased, is borne out by the actual cost of the installations in Manhattan and at Coney Island.

3 The capacity of the gas-operated Coney Island plant is 4500 gal. of water per min. against a head of 150 lb. per sq. in. The cost of the machinery is approximately $37,000 and the cost of the building approximately $10,000. The combined capacity of the two pumping plants in the Borough of Manhattan, as originally laid out, was 30,000 gal. per min. against a head of 300 lb., with provision in each station for three additional pumping units of a capacity of 3000 gal. each, making a total combined capacity of 48,000 gal. per min. against 300 lb. pressure. On actual test, however, the capacity of the pumps was approximately 20 per cent greater than the designed capacity.

4 Furthermore, the flexibility of this type of pump permits of an increased discharge at lower pressures, which gives a capacity of approximately 5500 to 5600 gal. per min. for pressures between 150 and 200 lb., or a combined total capacity of 55,000 gal. per min. against 200 lb. pressure. This corresponds to the pressure at which the station is operated for most fires. In other words, the water horsepower of one plant, as compared with the other, is approximately in the ratio of 20 to 1.

5 The first cost of installation of the gas-engine-driven plant is therefore more than double the first cost of installation of an electrically driven plant, in the city of New York. The cost of each of the two Manhattan pumping stations complete, exclusive of land, was practically $240,000.

6 The high-pressure fire-service pumping stations went into official operation on July 6, 1908. It was at first decided to put the stations in service only when called on by the fire department, and up to and including November 20, 1908, the pumping stations were called upon to go into actual service for but 17 fires. On that date, the method of operation was amended so that the pumping stations are put in service in response to every alarm in the high-pressure district, and continue in operation awaiting instructions from the fire department. Under this system, from November 20 to December 31, 1908, the pumps responded to 116 first alarms. From the best available information, water was used in 55 instances, making a

total of 72 fires for which the high-pressure service had been used up to that date.

7 To insure readiness for service at all times, daily tests are made, of at least half an hour's duration, unless the station has been in actual operation during the preceding 24 hours.

8 During the first quarter of 1909 the number of alarms received was 239, and water was taken from the station for 125 actual fires. The total amount of water pumped was 17,840,000 gal., and 145,900 kw-hr. was consumed. It was on January 7, 8 and 9 of this quarter that the three large simultaneous fires mentioned in Par. 75, occurred, for which over 14,000,000 gal. of water was pumped, leaving about 3,800,000 gal. for the balance of actual fires occurring during the quarter. For these three simultaneous fires more than 81,000 kw-hr. was consumed while the total consumption of power for the quarter for all fires and testing purposes was but 145,900 kw-hr.

9 As to why a pump running singly develops a higher efficiency than when running in conjunction with several others, it is observed that pumps of the same type do not necessarily develop their best efficiency at the same speed and pressure. The pump running singly will naturally develop a pressure which corresponds to its own design, but when working in multiple, it will have to adjust itself to the common pressure.

10 As to reliability I have neither seen nor heard of any time when any one of the ten pumps installed in the Borough of Manhattan has failed to respond instantly when called on for service and to develop the full pressure on the system within one minute's time. At no time in service have the pumps shut down of their own accord.

Henry B. Machen.[1] Among the many difficulties encountered during the construction of the distribution system, perhaps the greatest was that due to the congested sub-surface of the street, which was a source of continual extra expense to the contractor, and of worry to the man in charge of selecting the location for the excavation of the trench.

2 The intersection of Sixth Avenue and Fourteenth Street may be cited as an example, since complete notes are available, due to the station excavation for the Hudson Tunnels. Here there were nine gas mains east and west, and nine north and south, belonging to

[1] Engineer, Dept. Water Supply, Electricity and Gas, Manhattan Borough, New York.

four different companies; two water mains in each direction; sewers and their connections on each side of the street; five Edison duct lines, and five duct lines with large manholes belonging to the Consolidated Telegraph Subway Company or the Empire City Subway Company; the conduits and banks of ducts of the Fourteenth Street and the Sixth Avenue trolleys; and lastly, the columns of the elevated railroad with their deep foundations.

3 Through this network the high-pressure main had to be so laid that the construction of the Sixth Avenue tunnel would not require it to be relaid. The excavation was carried on by tunneling, with here and there an opening through which the earth could be hoisted, using a pail let down by a rope. The pipe was lowered into the trench some distance up the street and pulled through, piece by piece, inspection of the running of the joint and caulking being almost impossible, since the space admitted but one man at a time after the pipe had been hauled in.

4 This condition existed at nearly all intersections of the main thoroughfares, such as Broadway, Sixth Avenue, Fifth Avenue, the Bowery, etc., and accounts for the high cost of laying the mains, averaging about $11 per ft. complete.

5 The second great difficulty encountered was in obtaining the prescribed test, which called for 450 lb. pressure per sq. in. to be held for 10 min., during which time the leakage was measured.

6 The system contained about 40,000 castings, 30,000 being straight pipe, tested at the foundry to 650 lb. The specials were not tested. All these castings, as already stated, were tested in the ground to 450 lb., the mains being under pressure in sections about one block long, between gates.

7 During the eighteen months the system has been in service, there have been but three breaks in the mains, all three in castings which had been subjected to the foundry test of 650 lb., two breaking at 150 lb. and the third at 300 lb. pressure.

8 To overcome the danger should a break occur during a fire, the proposed extensions to the distribution system now under contract, amounting to about $1,500,000, are laid out on what the department calls the duplex system. This method of overcoming the difficulty was first suggested by Mr. Blatt, assistant engineer of the High-Pressure Bureau. It consists of laying two entirely independent systems of mains and hydrants in alternate streets, the hydrants of one system being painted red and the other green. The mains are so laid out that at nearly all intersections of streets hydrants of both colors are available.

9 Should a break occur in either system, the operator at the pumping station would at once know in which system the trouble was located by looking at the venturi meters, and by throwing a switch he would start the closing of two electrically driven valves, separating one system from the other. Hydrants would then be available and in service pending the location and isolation of the damaged section.

10 The section now in operation was designed to give 20,000 gal. per min. on any one block with a loss due to friction from pumps to hydrant not to exceed 40 lb. The duplex extension will give the same results, and should either half be out of service by an accident, there will still be available at the same location 10,000 gal. per min., with a loss from the pumps to the hydrant in the most unfavorable location not exceeding 50 lb.

Richard H. Rice. This paper shows that the installation described has been made after the most careful study and a very intelligent choice of the types of apparatus to be used. The choice of the centrifugal pump for the work described is thoroughly justified by its simplicity and by the efficiencies obtained. The choice of alternating current as the source of power, in view of the unlimited supply of current existing and the duplicate means of conducting it into the station, is also justified. The centrifugal pump is today the popular means of producing pressure for emergency fire purposes, as in the fire boats of New York, Chicago, Duluth and San Francisco, and the new high-pressure service of San Francisco. In San Francisco twelve of these pumps are now being installed, four on fire boats and eight for an auxiliary fire installation. On the fire boats centrifugal pumps are particularly adaptable as they can be run in series or in parallel. In parallel they give 150 lb. pressure, and in series the pressure is doubled. This pressure is particularly valuable where walls have to be battered down, or streams thrown long distances.

2 In cases where electricity is not so available as it is in New York, steam turbines are being installed, and they offer advantages over the gas engine, where maximum reliability is considered.

3 As an emergency installation pure and simple, I think the installation mentioned in the paper can be still further simplified. I believe the speeds chosen for operating the pumps are too low, and that the pumps contain too many stages. I have had occasion to make extensive researches in centrifugal pump design with special reference to operation at steam-turbine speeds, and have found that

they can be operated at high speeds with a smaller number of stages, giving efficiencies comparable with those obtained here, although the question of efficiency is subsidiary to reliability for this service. Pumps for this service should be designed with two or three stages at the most, and with considerably higher speed.

4 Pumps can also be designed without balancing pistons, which are undesirable from the viewpoint of possible interruption of service. An inspection of Fig. 5, illustrating the construction of the pumps, will show that the balancing pistons used are quite liable to damage if water containing sand or other impurities is used, and this damage would very probably result in stoppage of the pump when it is badly needed. The use of balancing pistons is unnecessary in such emergency apparatus and should be avoided.

C. A. Hague. A question has been asked several times with reference to the results of tests of efficiency on centrifugal pumps operating singly and in multiple or group. Professor Carpenter has given the very plausible explanation that the difference in efficiency in favor of the pumps running singly is probably due to the presence of eddies and disturbances in the pipes when the pumps are operating together and the absence of such eddies and disturbances when only one pump is at work. In my experience in installing pumps and condensers singly and in groups I have found them extremely sensitive to each other in operation, both in taking in and discharging the water, when more than one pump is working on a line.

2 In the Manhattan stations, it seems to me that the suction or inlet pipes and the discharge pipes are coupled too closely for best efficiency; and also that the inlet pipe close to the pumps is not large enough for operation in multiple, although perhaps ample for a single pump when the water is undisturbed by the draft and discharge of several pumps. I have experimented considerably in that line, and have found that a comparatively large body of water next to the pumps on the suction side will materially ease the machines in their performance. The idea is to come up to the building with a normal supply pipe, and then enlarge it very considerably just where it enters the building, providing the inlet pipe with a good-sized air chamber wherever possible. I have tried this several times with excellent results.

3 Mr. Brown mentioned the difficulty of cutting in with a second pump where the first pump was already running, a difficulty which

I think is also due to too close connections along the inlet and outlet lines and a cramped condition generally. Of course, a disturbance in the water column and in the hydraulic horsepower would unbalance the electric power to a certain extent, perhaps not much, but the total disturbance may very easily result in the loss of several points in the efficiency.

4 Considering the fact that the city pays by the kilowatt-hour for its electric current as per switchboard reading, it would be no more than proper to state the efficiency of the machine as a whole, and not exclusively upon the basis of motor efficiency obtained in the shop of the makers a thousand miles or so away. In this case when 100 h.p. in current is supplied to the switchboard, the motor has shown an output by a competent test of 93.2 h.p.—Par. 37—the 6.8 h.p., although charged against the city in the power bills, being lost in heat and friction. Then, all that is charged against the pump is 93.2 h.p. The 67.57 h.p. shown by the pump for each 100 h.p. at the switchboard indicates only 67.57 per cent total efficiency, although the 67.57 h.p. indicates 72.5 per cent efficiency of the power delivered by the motor. I have tested several centrifugal pumping plants of various sizes and powers, and the total efficiency generally shows from 64.5 per cent to about 68 per cent and very seldom above the latter figure.

5 Mr. Bibbins touched upon the possibilities of utilizing the centrifugal pump for waterworks service, but upon investigation he would find a vast difference between emergency service, where operating economy counts for little in the face of great danger from fire, and the steady and necessarily economical service required for the continual pumping in waterworks stations. To show how deceptive a portion of the truth may be, a case is cited where a pumpage of a capacity of 10,000,000 gal. per day against 110 lb. load could easily be accomplished with displacement steam machinery by an expenditure of $10,000 per annum for coal. But an attempt to drive centrifugal pumps by electricity resulted in a cost for electrical power, at $6.50 per 1,000,000 gal., of $23,725 per annum; showing a difference in favor of displacement steam machinery that would pay 5 per cent per annum on $275,940. There is no conceivable difference in cost of machinery, buildings, maintenance, attendance, or anything else, that would justify such a preference for electricity and centrifugal pumps over steam and displacement pumps. Note the following figures:

10,000,000 gal. daily, against 110 lb.	440 pump-h.p.
120,000,000 steam duty with 8 lb. evaporation in the boilers, coal at $2.50 per net ton delivered	$9928 per annum
Electric power at $6.50 per 1,000,000 gal. against 110 lb. means 3,650,000,000 gal. per annum at $6.50	$23,725 per annum
The difference in cost for the element of power is $13,797 per annum, which at 5 per cent would capitalize at	$275,940

6 The steam-driven, reciprocating, displacement pumping engine can show a mechanical efficiency, from the power put in through the throttle, to the water-horsepower of the pumps, as high as 96 per cent, never as low as 90 per cent, under the above conditions. The centrifugal pump when steam-driven has a corresponding efficiency of about 65 per cent, and when electrically driven of about 67 per cent. A comparison of tests is given in the tables, in which it will be seen that the steam plant saves enough to pay 8.6 per cent on its entire cost.

TABLE 1 COST OF OWNING AND PUMPING WITH HIGHEST TYPE AND CLASS OF STEAM PUMPING MACHINERY

One Unit, Steam-Driven, Reciprocating, Displacement Machinery, Capacity of 25,000,000 Gal. Against 87 Lb.

Pump horsepower	870
Boiler horsepower for triple-expansion vertical pumping engine	450
Engine house and foundations and engine foundations; Boiler house and foundation, boiler foundations, chimney, etc; Vertical triple-expansion pumping engine; 450 h.p. of boilers; Building for coal supply	$150,000

CHARGES AGAINST PLANT—PUMPING ENGINE

Interest	4 per cent
Sinking fund	5 per cent
Depreciation	2 per cent
Oil waste, etc	1 per cent
Total	12 per cent

CHARGES AGAINST PLANT—BOILERS

Interest	4 per cent
Sinking fund	5 per cent
Depreciation	5 per cent
Total	14 per cent

3 engineers. 6 firemen. 3 oilers.

Coal at $2.10 per net ton

Summary for Steam Reciprocating Machinery

Coal per annum	$11,957.40
Wages per annum	9,900.00
Capital charges on engine	13,920.00
Capital charges on boilers	1,260.00
Capital charges on buildings	1,548.00
Total charges per annum	$38,585.40
Cost per 1,000,000 gal	$4.11
Cost per horsepower	43 16

TABLE 2 COST OF OWNING AND PUMPING WITH HIGHEST TYPE ELECTRO-TURBINE PUMPING MACHINERY

One Unit, Electric-Driven, Centrifugal Machinery, Capacity 25,000,000 Gal. against 87 Lb.

Pump horsepower	870
Two-stage, electric-driven centrifugal pump Engine house and foundations and pump foundations Transformer house and foundations Transformers, lightning arresters, conductors, controllers and auxiliaries	$43,750

CHARGES AGAINST PLANT—PUMPING MACHINERY, ETC.

Interest	4 per cent
Sinking fund	5 per cent
Oil, waste, etc	1 per cent
Depreciation	2 per cent
Total	12 per cent

3 Engineers. 3 Extra men
Electric current, $4.50 per 1,000,000 gal.

Summary for Electric-Turbine Machinery

Electric current per annum	$41,062.50
Wages per annum	5,700.00
Capital charges on machinery	4,314.00
Capital charges on buildings	468.00
Total charges per annum	$51,544.50
Cost per 1,000,000 gal	$5.64
Cost per horse power	59.24

Thos. J. Gannon. In reply to Mr. Hague I will read the conditions which occurred on the evening of January 7, when both pumping stations were put to a crucial test:

7.22	First alarm, Hudson and Franklin Sts.
7.28	Second alarm, Hudson and Franklin Sts.
7.29	Third alarm, Hudson and Franklin Sts.
7.46	Fourth alarm, Hudson and Franklin Sts.
7.54	First alarm, Bowery and Hester Sts.
8.17	Automatic, Mercer and Houston Sts.
8.19	Second alarm, Bowery and Hester Sts.
8.29	First alarm, Mercer and Houston Sts.
8.32	Third alarm, Bowery and Hester Sts.
8.40	Second alarm, Mercer and Houston Sts.
8.43	Third alarm, Mercer and Houston Sts.
8.45	Fifth alarm, Mercer and Houston Sts.

2 In due time seven pumps were put into operation, with a discharge which reached at times over 35,000 gal. per min., and it was estimated that over 52 fire streams were in service at the same time. Each pump responded instantly and remained in service until ordered shut down. The pressure was ordered gradually increased from 125 lb. to 230 lb., where it was maintained throughout the greater part of the time that the fires raged. The operating force at each pumping station consisted of but one engineman, one oiler, one telephone operator and one laborer.

Prof. George F. Sever. A question was asked as to the feasibility of using the storage battery capacity to invert the rotaries and provide alternating current, to be spread through the alternating-current system to the sub-stations, and from those to provide alternating current to the pumping stations. In our preliminary investigation, if I recall the facts correctly, we were assured that this could be done; giving us another feature of reliability in the operation of the system. If the Waterside station should go out of business, we could still get current from the sub-station.

A. C. Paulsmeier.[1] While the reasons given in the paper for the selection of electric-driven turbine pumps do not coincide with the conclusions as to reliability that have been reached in the West, there can be no question about the careful study given by the engineers who planned the high-pressure fire system described.

[1] Chief Engineer, Byron Jackson Iron Works, San Francisco, Cal.

2 The pumps show a remarkable efficiency, and one of the principal points that should commend them to those interested is their great flexibility as to capacity, a characteristic that every fire pump should possess.

3 The eight fire pumps now being built for the City of San Francisco are of a combined capacity of 216,000 gal. per min., under a working pressure of 300 lb. Each of these pumps is driven by a 750-h.p. Curtis steam turbine, operating at a normal speed of 1800 r.p.m.

4 In addition there are now being completed four fire pumps for the boats Dennis Sullivan and David Scannel, of an aggregate capacity of 9000 gal. per min. under 300 lb. working pressure, or 18,000 gal. per min. under 150 lb. working pressure, the pumps being so arranged that they work either in series or in parallel. The pumps have all been subjected to 24-hr. tests, and while the data on these tests are not sufficiently complete for publication, it was shown that the pumps are not as flexible as to capacity, or are not as capable of pumping an excess quantity of water, as are the Manhattan pumps. The reason for this is that the impellers in the San Francisco pumps are only 13⅝ in. in diameter, while the inlet to the impellers is less than 10 in. in diameter, this opening being further restricted by the pump shaft, so that it is impossible to obtain much excess water from these pumps, no matter how much below the normal the discharge pressure is carried.

5 In the station pumps now being built the velocities at the entrance to the impellers have been somewhat decreased, although it is impossible to make anything like the excess capacity shown by the Manhattan pumps, which have impellers of such a size that the inlets may be made anything consistent with good practice.

W. B. Gregory. It is gratifying to know that efficiencies ranging from 70 to 80 per cent may be obtained with well designed five-stage turbine pumps. The high-pressure fire-service pumps in New York represent one extreme of conditions, while at the other extreme is the centrifugal pump used in the rice irrigation territory of Louisiana and Texas for raising large quantities of water through comparatively small lifts.

2 The improvement in design of pumps of the latter class in the last ten years, and especially in the last five years, has made it possible to specify an efficiency of 75 per cent, even with heads as low as 10 ft. Purchasers of pumping plants in this section are no

longer satisfied with pumping outfits having efficiencies ranging from 50 to 60 per cent.

3 As examples of the results obtained with pumps of the class that deals with large volumes of water, the tables are quoted from recent acceptance tests conducted by the writer, of pumping plants used for rice irrigation.

TABLE 1 ACCEPTANCE TESTS

TANDEM-COMPOUND CONDENSING ENGINES, DIRECT-CONNECTED

Cane and Rice Belt Irrigating Company, Fulshear, Texas, August 12 and 14, 1908

WORTHINGTON PUMPS	FIRST LIFT	SECOND LIFT
Size of pump (diameter discharge pipe), in	45	45
Water pumped, gal. per min	47,620	46,430
Head on pump, ft	33.90	13.95
Efficiency of engine and pump, %	69.5	73.6
Efficiency of pump (engine 93 %)	74.7	79.2

CROSS-COMPOUND CONDENSING CORLISS ENGINE, DIRECT-CONNECTED

Sabine Canal Company, Vinton, La., May 22, 1909

WORTHINGTON PUMP	
Size of pump (diameter discharge pipe), in	45
Water pumped, gal. per min	44,010
Head on pump, ft	23.26
Efficiency of engine and pump, %	69.5
Efficiency of pump (engine 90 %)	77.3

TANDEM-COMPOUND CONDENSING CORLISS ENGINE, DIRECT-CONNECTED

Second Lift, Neches Canal, July 16, 1909

MORRIS MACHINE WORKS PUMP	
Size of pump (diameter of discharge pipe), in	48
Water pumped, gal. per min	60,300
Head on pump, ft	10 12
Efficiency of engine and pump (maximum), %	69.9
Efficiency of pump (engine efficiency 93.2 % max.)	75

CHARLES B. REARICK. Electrically driven fire pumping-stations for large cities are dependent upon current from an outside source. usually a large central power plant. It would seem quite practicable in many cases to locate new fire pumping stations adjacent to some large power plant having considerable boiler capacity. In such cases it would be possible to drive the centrifugal or turbine pumps with steam turbines, and thus eliminate the necessity of large over-

load capacity in electric generating units for the central station, and also the liability of derangement of the lines between the power stations and the pumping stations. The charge for standby service per annum should be less than for similar electric service.

2 The steam turbines have the advantage of being operative at any speed, and in this manner will maintain in the discharge mains any pressure desired. Furthermore, automatic regulating valves can be used in connection with the turbine to maintain constant pressure irrespective of demand or flow.

3 It is probable that the cost of installation would be less than for electric-driven units. The turbine could run non-condensing, as the question of steam consumption is of small moment for fire service.

Henry E. Longwell. The last paragraph of the paper furnishes a striking illustration of how purely academic is the ordinary official efficiency test, and how valueless it is as a basis on which to predicate the results that may be expected when the plant is operated under normal service conditions.

2 The average net pressure against which the 14,095,000 gal. was pumped with a current consumption of 81,450 kw-hr. is not stated. Assuming that it was 300 lb. net per sq. in., the pump efficiency, after allowing for the losses in the motor, would be only 40 per cent. However we know that for part of the time the pressure did not exceed 225 lb., or, considering the pressure in the suction mains, about 200 lb. net. If the entire quantity of water had been pumped against this lower pressure, the efficiency would be well under 30 per cent. It is therefore perhaps fair to assume that the actual average efficiency was not far from 35 or 36 per cent, or say, in round numbers, only one-half that reported as shown on the official test.

W. M. Fleming. With the rapidly increasing size and height of office buildings, the annual fire loss in the business districts of the cities of the United States is increasing to an alarming extent. The installation of these tremendously effective fire-fighting systems has already proved of definite value in the reduction of city fire losses, and consequently of insurance costs.

2 What was probably the pioneer large and independent so-called high-pressure fire system in this country was installed at Philadelphia in 1903-1904. This plant differs in almost every important detail from the New York system more recently installed;

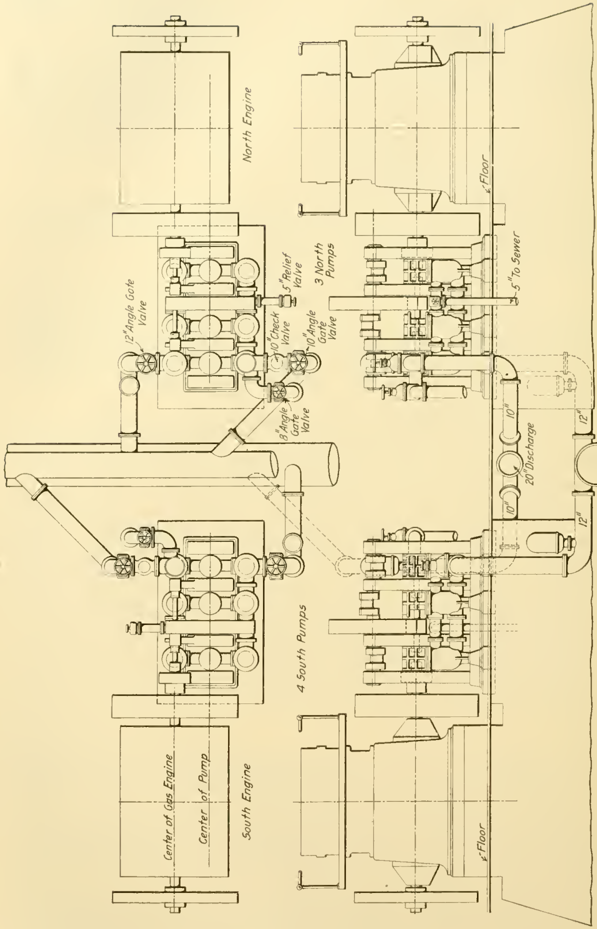

FIG. 1 GENERAL ARRANGEMENT OF THE PHILADELPHIA HIGH-PRESSURE FIRE-PUMPING STATION

yet the general results in both cases have been excellent. In Philadelphia the plant has so many times proved of great value in actual service that a much larger fire-fighting system, consisting of pumping units identical with those originally selected, is now being installed to protect what is known as the Kensington mill district.

3 From the original Philadelphia station at Delaware Ave. and Race St., a location unlikely to be seriously injured by conflagration, Delaware River water is supplied to independent high-pressure fire-service mains which effectually cover more than 425 acres at the center of the business district. The pumping units consist of vertical double-acting triplex power pumps built by the Deane Steam Pump Company, direct-connected to Westinghouse

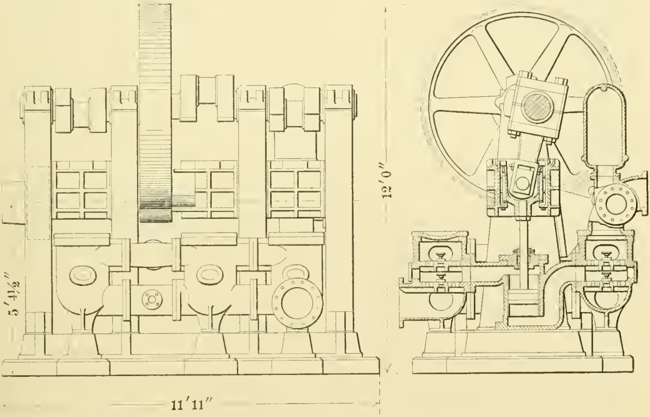

Fig. 2 Side and Sectional End Elevation of Triplex Pumps for the Philadelphia High-Pressure Fire-Pumping Station

vertical 3-cylinder 4-cycle gas engines each of 280 h.p. The seven large pumping units have each a nominal capacity of 1200 U. S. gal. per min., at 300 lb. pressure, and two small units have a capacity of 350 U. S. gal. at the same pressure.

4 The general arrangement of the Philadelphia pumping station is similar to that of the large New York installations. (See Fig. 1.) Two rows of pumping units occupy the main floor of the station. The pumps are nearest the center, and the gas engines are located in the same relative positions thereto as the motors in the New York

pump houses. A platform extending along the sides of the building, about ten feet above the floor, serves as a working gallery for the operation of the engine throttles. Space is provided for the installation of three additional pumping units, and all mains are proportioned with the ultimate probable capacity of the plant in view. Suitable connections are provided to the mains so that the capacity of the pumping station may be supplemented by the use of the city's powerful fire boats, should occasion require.

5 The internal combustion engines are of the well known standard Westinghouse type and require little explanation. Speed regulation with varying loads is accomplished by the action of a centrifugal governor controlling the quantity of combustible admitted to the cylinders. Ignition is by a very neat type of make and break mechanism contained in a cylindrical plug. Two independent igniters are provided in each cylinder, and three independent sources of ignition current are available at all times. The engines are started by the use of compressed air, which is admitted to one of the cylinders at the proper time to secure rotation in the direction required until the regular cycle of operation is established. The pumps are started under no-load.

6 The pumps are of the vertical, double-acting piston, triplex power type, requiring comparatively small floor space and giving a rate of discharge so smooth and uniform as to make imperceptible at the hose nozzles any pulsation in pressure.

7 Fig. 2 is a sectional view of one of the pumps, indicating quite clearly the extreme simplicity and accessibility of the machine, and its general construction. All valves are of the poppet type, readily accessible through handhole openings. Valve areas and waterways naturally are comparatively large, so that friction losses are reduced to a minimum. The water ends are thoroughly brass-fitted in order that the pumps may be readily started after a long period of disuse.

8 There is a connection through a 12-in. check valve, from the city mains to the high-pressure system, so that the mains and pumps are constantly primed with a pressure of 60 lb. and are ready for service at all times. A complete system of fire-alarm boxes and telephones, with underground wires, permits direct communication between the vicinity of any fire and the pumping station. On the sounding of the alarm, the station force, consisting of an engineer and his assistant, can bring the total plant of seven large units into service in seven minutes, and have repeatedly done so. Work-

ing pressure is invariably available at the hydrants one minute from the time of the alarm. Such a result would be impossible with ordinary movable apparatus.

9 The pumping units are started up under no-load, by the use of a motor-driven by-pass valve, through which the pump discharges into an overflow, until the normal cycle of operations has been set up in the gas engine, when the switch is closed, causing the by-pass valve to close and the discharge to be directed into the fire mains.

10 Experience has indicated that the maximum pressure of 300 lb. is required only for the most extensive fires, and for fires in the higher parts of tall buildings. The pressure records show that probably 75 per cent of the water pumped is required at not more than 150 lb. to 175 lb. pressure. The pressure desired in each case, is dictated over the telephone by the fire chief, the required pressure regulation being obtained by proportioning the number of units in operation to the requirements.

11 The practical results of the use of the Philadelphia fire system have been: material reduction in fire losses in the protected district, large decrease in fire insurance rates, and a greater willingness on the part of property owners in the protected section to erect pretentious office buildings.

12 Though the writer is unable to present a statement as to the annual saving to property owners by the installation, yet in view of the low cost of operation of the plant, there can be no question but that it presents a considerable yearly saving to the city. During the year 1907, which is perhaps typical, water was delivered to 16 fires, the longest one lasting 44 hr. The plant responded to 116 alarms at which no service was required. The operating expenses for the year were as follows:

Gas, 839,488 cu. ft. at $1.00	$839.49
Electric lighting	343.99
Electric power	7.98
65 tons pea coal at $3.50	277.50
Supplies furnished the pumping station for the entire year 1907	1,500.00
Total fixed charges for 1907	$2,968.96

Summary

Salaries (Total for entire staff)	$8,389.72
Total cost materials	2,968.96
Total operating expenses	$11,358.68
Total daily maintenance charge, salaries and operation	$31.12

13 No mechanical defects have yet developed in either engines or pumps, and practically the only replacements have been a few rubber valves for the pumps and ignition details for the engines.

14 While no definite comparison can be made between the small plant in Philadelphia and the comparatively large plants in New York, which have not yet been in operation for an appreciable length of time, the operating expenses of the Philadelphia plant seem likely to prove much less for a given quantity of service. This is largely due to the so-called "readiness-to-serve" charge made by the company furnishing power to the New York plants. To this charge must, of course, be added the actual cost of the current consumed.

15 Unfortunately no mechanical efficiency test has ever been made on any of the Philadelphia pumping units. Judging from tests of similar machinery, an efficiency of 80 to 85 per cent is to be expected from pumps of this character operating against 150 to 200 lb. pressure. If this is the case, knowing that 75 to 80 per cent of the water to be used will be required at pressures not to exceed 175 lb., it would seem that the plant efficiency in Philadelphia would prove greater than in New York, where we understand that the water must be delivered through reducing valves from 300 lb. to any lower pressure required.

Note: The discussion of this paper at St. Louis will be published later, with the author's closure.

STRESSES IN REINFORCED CONCRETE BEAMS

By Prof. Gaetano Lanza and Lawrence F. Smith,[1] Published in The Journal for Mid-October

ABSTRACT OF PAPER

This paper presents a comparison, in the case of eleven beams, of (*a*) the position of the neutral axis, (*b*) the stress in the steel, (*c*) the greatest compressive stress in the concrete, (*d*) the greatest deflection of the beam as determined by experiment, with the same quantities as computed by each of three well-known theories of the distribution of the stresses, these theories being designated by *A*, *B* and *C* respectively. *A* and *B* both neglect the tension in the concrete, but differ in the mode of distribution of the compression; while *C* takes account of tension in the concrete. The results show a better agreement with the results of the experiments when tension in the concrete is considered than when it is not. This is especially so in the case of the stress in the steel and in the position of the neutral axis, and, to a lesser degree, in the greatest fibre stress in the concrete and in the deflection.

DISCUSSION AT BOSTON

Chas. T. Main. All engineers, civil, mechanical or any other, want to know the most accurate way of figuring the stresses in reinforced concrete. What I am more anxious to know is that the proper ingredients are used, with proper mixing and good workmanship, so that we may be reasonably sure of a factor of safety in the finished work somewhere near what was intended. I have done no work of this sort without constant supervision, and am obliged to say that I have done no work that has been a source of pleasure to me. All of the building materials in common use are, I think, more certain in results than reinforced concrete. It is quite necessary to improve in the use of this material and in workmanship, in order to produce work which will inspire confidence.

[1] Instructor, Mass. Inst. of Tech.

Sanford E. Thompson. Professor Lanza's paper is of much value as a means of comparing the various formulæ used in designing reinforced-concrete beams, with the behavior of test beams under load. Of the three theories the straight-line theory A is the simplest, and to the writer this still seems the best from a practical standpoint.

2 The formula derived by this theory as now used for determining the depth of a reinforced concrete rectangular beam (using the notation adopted by the Joint Committee on Concrete and Reinforced Concrete[1]) may be expressed simply as

$$d = C\sqrt{\frac{M}{b}}$$

and the ratio of steel required is $A_s = pbd$

where d = depth of beam from compressed surface to center of steel, in inches.
C = a constant for a given steel and a given concrete.
M = moment of resistance or bending moment in general, in inch pounds.
b = breadth of beam, in inches.
A_s = area of cross-section of steel, in square inches.
p = ratio of cross-section of steel to cross-section of beam above the center of gravity of the steel.

3 Theory B, where the stress is taken as varying according to a parabola, is perhaps more exact than theory A, but at the same time more complicated and difficult in practical application. Theory C agrees more closely in the earlier stages of loading with the tests, although tests made both in the United States and in Europe indicate that Considère was not entirely correct in his assumption that steel when combined with concrete permits the concrete to stretch to a greater degree than when not reinforced. However, at earlier stages of loading the cracks in the concrete do not extend up to the neutral axis, so that more or less of the concrete is resisting tension and assists the steel in taking the stress. For this reason a method taking into account the tensile value of concrete gives results closer to the tests at early periods of loading than either formula A or B.

[1]The Joint Committee is composed of representatives from the American Society of Civil Engineers, the American Society for Testing Materials, the American Railway and Maintenance-of-Way Association, and the Association of American Portland Cement Manufacturers.

There are, however, quite important reasons, as will be shown in succeeding paragraphs, why theory A is preferable.

4 Reinforced concrete is a complex material, which if properly used gives very safe and satisfactory structures. It is not, however, of a kind to which hair-splitting accuracy may be applied. In selecting a formula to use, the aim should be to choose one which will give results always on the safe side and at the same time not very wide of the mark. Referring to the paper, formula A gives results on the safe side, while C errs nearly as often on one side as on the other.

5 The behavior of a reinforced-concrete beam under load may be divided into two stages, the earlier stage where the concrete under the neutral axis bears tension, which gradually merges into the later stage, when the tensile strength of concrete is overcome and all the tensile stress is taken up by the steel. In the earlier stage the stress in steel increases proportionally to the moment, while in the later stage the increase in stress in steel is composed not only of the increase proportional to the moment, but also of the stress which in the previous stage was carried by the concrete and after its cracking transferred to the steel. Thus, for example, if a certain load W stresses the steel up to, say 16,000 lb. per sq. in., an addition to the load of *less* than W will double the stress. Therefore, a beam designed for a load which would produce an actual stress in steel of 16,000 lb. per sq. in. would have a factor of safety smaller than the ratio of that stress to the elastic limit of the steel. It is safer, then, to base the design on the results at the breaking load rather than on the results at earlier stages of loading, and to use theory A, which at the breaking load corresponds closely to the tests, and so be sure of the required factor of safety. In designing, working stresses and working moments should be used in the formulae.

6 The strongest argument against computing the concrete to bear tension, in practical design, is the fact that reinforced-concrete floors and other structures usually have to be built with joints between two days' work. The bond of the concrete on the joints is imperfect, and consequently the tensile strength of concrete at that point is small and cannot safely be counted upon in design.

7 Theory A is very simple and clear. It has been adopted quite generally in Germany and England, and I believe also in France, although that is the home of Considère, while the Joint Committee in this country has recently adopted it.

8 Theory A when used in figuring deflection does not give very satisfactory results, but this is not an important factor in reinforced-

concrete design. When necessary to compute deflection, a more complicated formula may be used which considers the tensile strength of concrete. The best of such formulæ known to the writer are those derived by Professor Thullie of Austria, which are based on more logical assumptions than are the formulæ of Considère.

9 It must not be forgotten that the computation of the stress in the middle of a supported beam is only one part of the theory of reinforced-concrete design. Just as important as the design of the beam in the center, since reinforced concrete is usually built continuous over several supports, is the design of the ends of the beam, and of no less importance is the part of the design to resist the tendency of the diagonal tension to produce diagonal cracks.

10 It may be said then in conclusion, that although not corresponding strictly with tests, the ordinary straight-line theory is the one which will probably be used for some time to come because of its simplicity, and because reinforced-concrete beams, designed according to this theory, with due regard to other details, will produce with good workmanship, structures which are unquestionably safe and conservative.

11 Except for a few isolated examples, it is less than ten years since reinforced-concrete buildings began to be erected; the 16-story Ingalls building in Cincinnati was built in 1903, and still stands as the most notable example of a concrete office building. And yet, as has been stated by Professor Burr, we already know more about concrete columns than about steel columns; the tests have been more exact, and more nearly conform to practical conditions. The beam theory is still in the stage of development, and tests and mathematical demonstration which tend toward more economical and rational detailing are welcome. Nevertheless, we may say with surety that buildings all over the country which are being designed by the common formulae with conservative stresses, and erected with proper care, are safe and conservative.

F. S. Hinds.[1] I have had a very profitable experience in the last two or three years in the construction of a large office building built entirely of reinforced concrete, erected for the Phelps Publishing Company at Springfield, Mass. The building covers an area of 30,000 sq. ft. and is eight stories above the sidewalk. In the construction of the building it was demonstrated that good work can

[1] F. Sumner Hinds, Boston, Mass.

be done with reinforced concrete, and that there was no mistake in selecting concrete for both the interior and the exterior of the building.

2 My observations have led me to believe that we will see this construction in buildings even higher than eight stories. In fact, there is such an office building in Cincinnati, 16 stories above the sidewalk, showing that reinforced concrete can be used in competition with the steel frame.

3 Answering a number of questions by Desmond FitzGerald, Mr. Hinds said that the concrete for the building was mixed by machine, crushed stone of "pea" size being used. The proportions of the mixture were 1-2-4, just enough water being added to make the mixture solid and yet make it flow easily. The ramming of columns was not done in the usual way, but the concrete was settled by means of four or five poles. Both round and twisted rods were used, held in place by small wood blocks which were withdrawn as the mixture was poured into the form.

4 Continuing, Mr. Hinds said that the great secret in concrete work is in getting the rods in the proper places. Supervision and careful preparation of the mixture and handling of materials will bring the best results. An oil paint and cold water paint without plastering have been used on the inside of the building, showing how smooth the surface was finished.

5 In answer to a question Mr. Hinds said that moisture was prevented from going through the walls by their thickness—none being less than 8 in. thick—and by the density of the concrete. He had seen no cracks whatever in the reinforced concrete proper, the only crack in the building being one near the top of the elevator-well partition, caused by expansion and contraction. Here and there a small crack appeared in the granolithic floor.

Prof. C. M. Spofford.[1] I presume we all agree with the previous speakers that concrete should be handled carefully, as it is subject to great variations. I feel, however, that merely to be careful is not enough; we should determine the theories as correctly as possible, and use them to eliminate so far as possible such uncertainties as now exist.

2 I am surprised that the C formula, as Professor Lanza has called it, gives results closer to the results of actual experiments than

[1] Massachusetts Institute of Technology.

the other formulæ, and hope that the present data may be extended by further tests and computations. As far as actual use in design is concerned, any one of these theories may be safely used, provided a liberal factor of safety is employed, but further study and investigation along the lines indicated may enable us to determine more precisely what the factor of safety should be.

Henry F. Bryant.[1] I would like Professor Lanza to tell in what way the tested beams failed; whether there were distinct signs of failure at the yield point of the steel, and whether that is the definite point of failure in the beams which he tested. I would also like to ask whether as a result of the tests, he has any evidence that exceeding the yield point of the steel, if it is reached without diagonal crack, is the cause of the failure of the beam.

J. R. Worcester.[2] The careful study which the authors have devoted to these eleven beams is of great value, and their deductions show how much can be learned from a few experiments made with care and recorded with scientific accuracy.

2 It seems to the writer, however, that a few other points of interest in the tables are worthy of comment; as, for instance, the fact that in two of the beams, A-1 and A-2, alike so far as dimensions and amount of reinforcement are concerned, there appears to be a variation of 0.1 in. (1.9 per cent) in the actual location of the neutral axis; of 76 lb. per sq. in. (12 per cent) in the stress in the concrete; of 297 lb. per sq. in. (3.9 per cent) in the stress in the steel, and of 0.007 in. (10 per cent) in the deflection.

3 Another remarkable variation in the behavior of beams apparently alike is that of No. 35 and No. 45, where the latter with 80 per cent of the load of the former had the same actual deformations in steel and concrete, indicating the same location of neutral axis, and at the same time 50 per cent greater deflection. These great differences may perhaps be due to the fact that No. 45 was cracked before the test began, and therefore possibly should be excluded from such a comparison as this, though the cracking did not prevent the beam from developing fairly satisfactory strength. These striking instances of variation in observed results, where every precaution was taken to make the conditions identical, render it important to select theories of computation safe for the worst results found experimentally.

[1]Henry F. Bryant, Boston and Brookline, Mass.

[2]J. R. Worcester, 79 Milk St., Boston, Mass.

4 Speaking from a practical standpoint, several of the elements compared are not of vital importance. The location of the neutral axis is used only as an intermediate step in the process of calculation, and, if fairly correct results can still be obtained, error in this part of the calculation is not serious.

5 Then, again, the deflection is rarely of great importance. It is comforting to know that beams do not deflect as much as if the concrete had no tensile strength, but practically this is as far as we are usually concerned.

6 The actual compressive stress in the concrete may also be eliminated from consideration in actual construction, if only we can limit the area of steel to such a percentage that we are sure failure from the compression of the concrete will not occur until the steel has been stretched beyond the elastic limit. In this connection it is worthy of note that the beams quoted were with one exception more heavily reinforced than is usual at the present time. With 0.8 per cent of steel, or even with 1 per cent, it is safe to base our calculations for moment upon the stress in the steel only.

7 The element then about which the most interest centers is the stress in the steel, and it is important that we should adopt a method of computation which gives this with the least error practicable, and with that on the safe side.

8 Looking at Table 5 with these considerations in mind, we find little difference between methods *A* and *B*, both giving results well on the safe side. Method *C*, while averaging very closely to actual results; gives errors on the wrong side in five out of the eleven cases cited, in one case, and that the one most resembling usual practice, having an error of nearly 15 per cent on the unsafe side.

9 It is noticeable also that the loads assumed are considerably less than what would usually be considered working loads for the beams in question. Following almost universal practice at the present time, the stress in the steel as computed would be allowed to go to 16,000 lb. per sq. in. This would permit loads on the University of Illinois beams as follows:

No. 11, 5,000 lb. in place of 4000 lb.
No. 27, 12,000 lb. in place of 9000 lb.
No. 28, 10,000 lb. in place of 5000 lb.
No. 33, 7,000 lb. in place of 5000 lb.
No. 35, 8,000 lb. in place of 5000 lb.
No. 45, 8,000 lb. in place of 4000 lb.

Only these six are quoted because the essential facts regarding

them are given in the bulletins of the University of Illinois, while we have not at hand the details of the tests at the Massachusetts Institute of Technology.

10 The diagrams of these beams indicate under the above loads the stresses in the steel indicated herewith, using the authors'

STEEL STRESS UNDER HEAVIER LOADING

Beam No.	Load Used	Stress in Steel, Lb. per Sq. In.			Error of Calculation Per Cent	
		Actual	By A	By C	By A	By C
11	5,000	15,600	17,700	13,600	+13.5	−12.9
27	12,000	13,500	14,900	12,600	+10.4	− 6.7
28	10,000	14,700	16,600	15,000	+12.9	+ 2.0
33	7,000	12,600	15,200	12,900	+20.6	+ 2.4
35	8,000	13,800	15,750	13,900	+14.1	+ 0.7
45	8,000	15,000	15,750	13,900	+ 5.0	− 7.3
				Average error	+12.75	− 3.6

modulus of elasticity, 30,000,000 lb. In the same table are given the stresses in the steel as calculated by methods *A* and *C*, and the percentage of error by each method.

11 Comparing these results with those obtained by the authors as shown in Table 5, we find that the common method of computation *A* gives considerably closer results to those observed than under the lower loading. The error ranges from 5 to 20.6 per cent, with an average of 12¾ per cent, always on the safe side. On the other hand, by the Considère method, *C* varies from + 2.4 per cent to − 12.9 per cent, with an average of 3.6 per cent on the unsafe side. This would indicate that there is no advantage in adopting the more laborious method, involving the solution of an equation of the fourth degree, at least so far as proportioning the steel is concerned.

12 The chief difference between the two methods, as explained in the paper, is in the assumption in the Considère method of a certain value for tension in the concrete below the neutral axis, and the disregard of this in method *A*. There is no question that under ordinary conditions the concrete has a small amount of tensile strength while the loads are small, but there is grave doubt as to the safety of relying upon a crystalline material under such conditions. Many conditions in actual construction may tend to destroy the tensile strength.

There may be set-joints near the center of the beam; there may be voids near the bottom where the mortar has leaked out; there may be incipient invisible cracks extending to an unknown distance. It is a fortunate circumstance that ease of calculation is on the side of the safer method, for this is a powerful incentive to its adoption.

13 The statement at the opening and close of the paper that "the observations made thus far are not sufficient to furnish means for determining the actual distribution of the stresses," etc., is undoubtedly true, speaking literally and with scientific accuracy. At the same time it should be borne in mind that we are dealing with a crude product which cannot in practice be made with scientific accuracy. It is doubtful whether absolute knowledge of the laws of distribution of stress in a theoretically perfect material would be of any great advantage in designing structures of every-day material. The important question is whether we know enough to design our beams with entire safety and reasonable economy. To this query the writer would unhesitatingly give an affirmative answer. The investigation of these beams tends to confirm this opinion, which is also supported by the constantly accumulating experience with actual construction. We would therefore venture to add two other conclusions to those advanced by the author, namely:

a Experiments indicate that, though precise determination of the laws of stress distribution may be impossible in the present state of our knowledge, sufficiently close approximations may be made for all practical purposes.

b The simple method of calculation, by neglecting tension in the concrete and assuming a straight-line distribution of the compressive stress, is the easiest to apply and gives satisfactory results for the determination of the stress in the steel.

Prof. Geo. F. Swain. I notice that Professor Lanza has used a value of $E = 2{,}335{,}000$ for the beams tested at the Massachusetts Institute of Technology, while for the beams tested at the University of Illinois he has used a value for E of 2,000,000. The beams tested at the Massachusetts Institute of Technology were from 35 to 54 days old, while the beams tested at the University of Illinois were from 60 to 65 days old. The modulus of elasticity ought to increase with age, other things being equal, yet in these tables the reverse is assumed. This fact might account for some of the peculiarities

and the results. Professor Lanza does not state whether he measured the modulus of elasticity.

2 In Table 2, I think the heading of the column "Nearest one-third Load," is a little confusing. Those figures are not very close to one-third the load, and beam *C*-5, which has a larger load than the first three beams, has a smaller value in the third column. I suppose the third column simply means the loads for which computations were made, and that the loads were applied in such increments that the figures given represent the nearest third of the load for which computations were made. Yet it seems rather confusing that for a load of 16,240 lb., the nearest one-third should be given as 4600 lb.

3 With reference to the three theories, I have never believed in Considère's main contention, namely, that by reinforcing concrete such great strains could be produced without fracture; though his explanation is in a certain degree plausible. If a body is stretched so that the molecules are a certain distance apart, nothing can prevent fracture. Ductile material like steel draws down at the point of fracture and is stretched much more there than on the average through the length of the piece. If concrete were a ductile material, its adhesion to the steel bars might prevent any such phenomena as drawing down and thus distribute the strain; but concrete is not a ductile material, and there seems to my mind to be no possibility of the great stretch without fracture which Considère claims.

4 As to the results obtained by the three formulae, I think those given in the tables were precisely what might be expected, because these loads were only large enough to be called working loads; that is, they were nothing like the ultimate load. As a matter of fact there was tension in the concrete, under which condition the steel would be relieved; we would therefore expect that in case *C* the stress in the steel would be very much less than in the other two cases. In practice, also, there is undoubtedly tension in the concrete unless cracks occur. The results of tests made by the Boston Transit Commission show large tensile stresses in concrete beams without reinforcement.

5 However, the question is, what to do in designing. In practice there may be cracks in the concrete, not due to stress, but to the moving of blocks on which the rods are set, making the cement run out, or due to shrinkage or joints or other causes; for which reason it seems to me that in practical designing, engineers are not justified in assuming any tension in the concrete.

6 If Professor Lanza tested the modulus of elasticity of his beams,

I would like to know what was the variation in the moduli of elasticity. Was 2,335,000 the average? How did the separate values compare?

Henry F. Bryant.[1] Mr. Worcester stated (Par. 9) that on applying his reasoning to the University of Illinois experiments, the nearest one-third load for 16,000 lb. of stress on the steel would be found to be nearly double that given in the paper as approximately one-third the breaking load. This emphasizes the question of the yield point. The rather common practice, as Mr. Worcester states, is to take from 12,000 lb. to 16,000 lb. on mild steel and with this to use about 500 lb. as the concrete compressive strength, which, with concrete of 2000 lb. compressive strength, gives a factor of safety of four or possibly five. If the yield point is the critical point in the steel, we are using a factor of safety of only between two and three in the steel. Mr. Worcester's analysis of the Illinois experiments would indicate that instead of breaking at three times what would be considered a safe working load, the beam would break at not over twice the load. I think that using mild steel and a factor of at least four, and figuring that the yield point is the critical point of the steel, we should apply to the steel something like 7500 lb. or 8000 lb., with 500 lb. compression on the concrete. That means a little larger percentage of steel than is common practice, though it is not unusual to adopt this reasoning with high-carbon steel. I am very glad to see that these experiments point that way.

Rolf R. Newman.[2] Several technical journals have commented on Professor Marburg's tests of Bethlehem steel, in which he obtains some very low values, saying that they considered a well made concrete beam safer than a large Bethlehem beam, because its composition is more definitely known. I would like to ask Professor Lanza whether in his opinion it is correct to say that as much experimenting is needed upon large Bethlehem beams as upon reinforced-concrete beams.

H. E. Sawtell.[3] Considère's theory of stress distribution agrees very well with the actual tests at about working loads on the eleven beams mentioned in the paper. We know, however, that his theory

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[2] Civil Engineer, Boston, Mass.
[3] Structural engineer, with Chas. T. Main, Boston, Mass.

will not agree with breaking-load results as well as either the straight-line or the parabolic theory, which consider that concrete takes no tension stress. We should adopt a theory which will agree quite closely with tests at breaking loads, but which will always be on the safe side for intermediate loads. We can then get a real factor of safety.

2 Referring to Par. 24, it seems likely that when applied to floor beams, a formula will remain only a sort of working hypothesis if our theories are to be based upon test beams which are not more like the beams used in actual practice, and if our compressive value for concrete is based upon plain concrete. The present uncertainty may appear to favor the side of safety, but on the other hand, when too

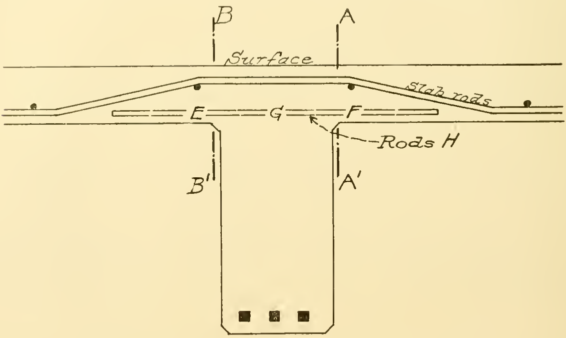

Fig. 1

many assumptions have to be made, there is little real satisfaction in working with the material.

3 Tests on rectangular beams are necessary for determining as nearly as possible the stresses and deflections in slabs and separately moulded beams, but do not seem to solve the problems of beams and girders as used in actual construction. Let us first note some of the stresses as they exist in a beam in actual construction, assuming Fig. 1 to be the cross section of a beam at its place of maximum flexural stress. The slab steel is placed at the beam, as a great many designers consider necessary, in order to resist fully and reliably the negative slab stress, etc., at the beam. These slab rods always are only a few inches apart, and pass through the top of the beam concrete at right angles to the compressive stress of the beam.

4 Assuming that the concrete in both beam and slab is poured at the same time, we know of course that for some distance each way from the beam the slab will work with the beam in resisting compressive stresses. Assumptions are made as to what part of the slabs will work safely with the beam, and then the beam is calculated for and designed as a T-beam. In doing this the full working stress for concrete in compression is used. The concrete at *G*, *E* and *F* has a large share of the compression to take care of. Also, as a result of placing the slab steel at the top, as it passes over the beam, the concrete at *G*, *E* and *F* is again put in compression, this time at its full working value, but at right angles to the compressive stress in the beam.

5 Again, the maximum vertical shear in the slabs is along the lines *B-B′* and *A-A′*, this shear, it will be noted, being through concrete already doing double duty in compression. The concrete at the surface is at the place of maximum compressive stress of the beam and it also has a maximum tensile stress due to the negative slab moment.

6 The total compression at *G*, *E* or *F* is very much higher than we would willingly put upon plain concrete as a working stress, while the concrete at points *E* or *F* is in a worse condition. At the surface the material is nearly cracking from a tensile stress, even under working loads, and it cannot be of much service in compression where it is most needed by the beam.

7 If these conditions are correctly noted, and if the actual stresses are to be kept down to the unit working stress of *plain* concrete, then it will be necessary either to assume a much lower unit stress for concrete when designing T-beams, or to design a rectangular beam whose effective top surface does not extend above the slab rods shown in Fig. 1. But is it necessary to use the value of plain concrete when designing T-beams? Are we not justified in saying that concrete at *G* is confined, and being reinforced, has a much higher ultimate strength than plain concrete?

8 The compressive strength of concrete in beams is increased in two ways (*a*) by lateral restraint, brought about by the surrounding compressive forces; (*b*) by reinforcing its shearing resistance, which may be greatly assisted by placing the rods *H* at the points shown in Fig. 1. These *H* rods are to be used only at and near the place of maximum moment in the beam and should be quite close together.

9 But how much does this increase the strength? As bearing upon the subject, an extreme case may be cited from a paper by Leon S. Moisseiff read before the American Society for Testing Materials.

The compressive strength of cubes of concrete, reinforced in every direction by a large percentage of metal in the form of nails, was increased to two to three times the strength of plain concrete. Some designers have already noticed an increase of strength under similar conditions and are taking advantage of it, but are making assumptions regarding its amount for different percentages of reinforcement.

10 So far as the writer knows, no T-beams have been tested with their flanges reinforced and loaded in such a way as to carry their loads to the beam and thus to strain the beam in the same manner as in actual practice. It seems that future tests should be along such a line, if greater economy is to be reached in design and our knowledge is to become more exact with fewer assumptions made.

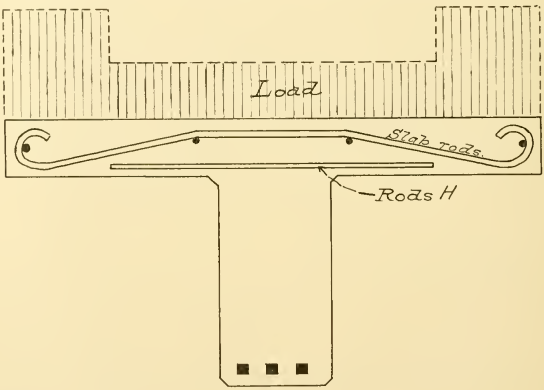

Fig. 2

11 In conclusion, it would seem as though the slab concrete were overstrained at E and F, where it is used for T-flanges, for negative slab compression and for vertical shear from slab loads. Unless it can be ascertained whether lateral restraint, and the use of the rods as shown, will increase the strength necessary to resist this strain safely, it would be better not to calculate for T-beams, but to make the rectangular section sufficient to meet the stress. Even this rectangular section should be designed with a conservative concrete compressive stress, because its top surface is generally considered at about the point where the slab rods pass over it, this including the concrete at G.

12 Fig. 2 shows the cross section at the center of a T-beam, and a method of loading which seems to give promise of results which will come nearer to showing how beams in actual construction are stressed than rectangular beams whose compressive side is wholly plain concrete. The load over the stem should be less than the flange loads; and should agree with actual floor loading where the slabs carry most of the loads to the beam and produce tension in the rods and concrete at the surface over the stem, compression at the under side of the slab at the stem and shear near the stem. As tie rods are always used in practice it would be well to use them here. They are shown by dots in the diagram. The slab rods in this case are bent to act as anchors, and the tie rod at the edge is wired to them on the inside.

13 It is acknowledged that the loads on the flanges do not stress them quite as they would be stressed in a floor system; but if the compression, tensile and shear stresses are not more than those that would be produced, were the slabs continuous, it is thought that as their stress is at right angles to the beam this difference will make no practical difference with the results on the beam.

DISCUSSION AT NEW YORK

E. P. Goodrich.[1] The several theories which were the basis of the formulæ used by Professor Lanza are approximations to actual conditions, and are made the basis for calculating special points in construction work. The first method is used primarily because of its ease of application to ordinary conditions, and the factors now introduced into the formulæ are based almost exclusively on the results of actual tests. For instance, in the particular series of tests made at the Massachusetts Institute of Technology the ratio of the modulus of elasticity as found by experiment to the computed value is only eight and a fraction. On the other hand, diagrams of Professor Talbot's beam tests, in which the position of the neutral axis is shown, give a ratio of more nearly eighteen, showing that the factor introduced has no real relation to actual conditions. It is the adaptation of a formula to tests, rather than the use of a formula to check various kinds of investigations. Occasionally the straight-line formula has been used to compute deflections and stiffness, as was reported not long ago in an article published in Engineering News; but as to the accuracy of this use there has been some adverse criticism.

[1] Consulting Engineer, 1 Madison Ave., New York.

2 As has been said, Considère's theory was based on certain experiments, the accuracy of which has also been questioned. Professor Mörsch of Zürich argues both for and against them in his book entitled Eisenbetonbau, describing certain experiments with concrete beams, in which he determined the stress-strain diagram for both tension and compression, finding some such conditions as that shown in Fig. 1. If in any beam section, the neutral axis be established, and the actual stresses laid down graphically above and below this neutral axis at any point, and if the centroids in each section are determined, and the distance between them measured, the moment which must theoretically be sustained by the beam can be computed. Mörsch tested

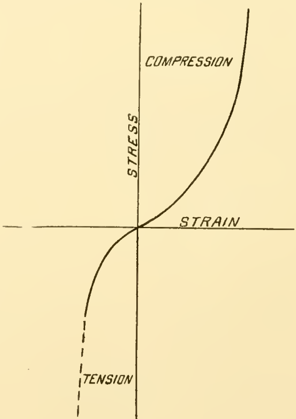

Fig. 1

some specimens both in compression and tension, and also in bending, and computed the theoretical bending moment and ultimate strength by methods similar to Considère's, using a practically constant stress in the concrete below the neutral axis. He found that the theoretical bending stress in kilograms per square centimeter was 20.7, while that found as an average of three actual experiments was 21.4, showing a very close agreement in this particular instance.

3 In the case of three other beams in which the percentage of steel varied from one-half of one per cent to very nearly two per cent, Mörsch made a similar computation based entirely on a stress relation

similar to that of Fig. 1. He found the resultant of the two tensile stresses, in the concrete and the steel, then measured the distance on his diagrams between the centroids of compression and tension, and computed the moment, which was found to correspond closely with the test conditions.

4 Another series of tests of considerable interest is that made by Dr. Mueller for his doctor's thesis for the Hanover Technical High School. He treated concrete beams in a manner similar to that of Professor Lanza, except that he used thirteen points in the depth of the beam, and measured by three methods the actual strain relation which existed at different times. In all his work he used simply a safe working stress, to the limit allowed by the German Government regulations. He found that in a solid beam the stress varied to a certain extent, was very nearly of the straight line type when measured at all his thirteen points; while with a beam in which he built in fourteen artificial cracks by putting sheets of metal close together in the beam, he found that the stress relation more nearly corresponded

Fig. 2

with Considère's theory These artificial cracks produced a variable stress between the sections, so that the stress in the steel was actually less between the cracks, some of the stress being thrown into the concrete, as illustrated graphically in Fig. 2, in which the ordinates above the base measure the tensile stress.

5 The question of shear has been mentioned, but its effect upon deflections has not been discussed. The writer believes this is very important, because of two series of tests which he made some years ago on beams, one series of which was reinforced only by horizontal rods, and the other by vertical stirrups also. The deflection was three or four times as much in the case of the beams without the vertical steel—shear reinforcement—as in the case of beams with considerable vertical reinforcement. Each series had exactly the same amount of steel in tension. Of course theoretically the vertical stirrups could not affect the tensile stresses in the bottom of the beam. The ordinary theory by which deflection is computed does not include

a factor for shear, which actually does have some effect on the deflection, both theoretically and, as shown by these tests, practically. It must be taken into account, as well as the tension in the concrete, if the actual conditions in the beam, especially with regard to stiffness and deflection, are to be considered.

6 It seems necessary that some relation between deflection and stress should be definitely determined, because deflections can be more easily measured in any beam test than any other phenomena. Almost every novice determines the deflection, although he does not know the relation between it and the stresses involved. It is only through discussions such as this that some true basis can be reached for the computation of the stresses involved in continuous members.

7 There is another point concerning which the writer has made some experiments. By means of plaster of Paris, ordinary sharp carpet tacks were applied to the sides of a beam, with the points sticking outward. The beam was loaded centrally, and the actual deflection curve was simply picked through a piece of paper from time to time as the load was increased. The curves were then enlarged and used as a basis for comparison with the theoretical elastic curve of a beam loaded centrally. There was a very large discrepancy, which was more nearly coördinated when it was assumed that the load was distributed over a length something like one and one-half or two times the height of the beam. It is to be hoped that experiments will be made in regard to the deflection of beams and the distribution of stresses, so that some true relation can be determined, between this element, which is easily measured, and the other elements which are usually unknown: that is, in regard to the relation between deflections and the actual stresses of compression and tension.

Prof. Walter Rautenstrauch. I regret that more observations are not recorded and plotted in the paper and that the methods of making the computations and obtaining the data are not given. It would be interesting to plot the variation of deflection with load as observed, and as computed by the three formulæ selected for comparison.

2 I would ask Professor Lanza how he made his observations for the strain in both concrete and steel and also how he determined from these the neutral axis of the section. If these data were submitted it would be possible to make a comparison with results obtained by assuming other possible values of E, for example, and thus to ascertain to what extent the differences reported might be due to assumed and possible actual values.

3 As concrete construction is for the most part monolithic, and very few beams of the particular kind tested are used, I believe it is of much broader interest to investigate methods of measuring strain and computing stress than formulæ for simple beams. It is a fact, I believe, that all the data reported in this paper as actual stresses in concrete—actual stresses in steel—were obtained, not actually, from direct observations, but rather from relations between stress and strain assumed to exist in the concrete or steel. The same I believe is true in regard to the determination of the neutral axis. If Professor Lanza will tell us what assumptions he made in determining these values we will be in a better position to judge their worth.

4 I need hardly call attention to the fact that the modulus of elasticity for concrete in tension and compression is quite variable. It seems to depend upon the age of the concrete and the intensity of the stress. I believe it would have been of some value to take a slice from the end of these beams and obtain a stress-strain diagram, in order to compute the several values of E and the limits of stress for which each value of E is constant. Otherwise the actual values of the stress are not much more reliable than the values as computed by the formulae, since both are computed from assumed relations.

5 It is interesting to note that Formula B is based on a rational assumption concerning the variations in compressive stresses above the neutral axis. The fact has been well established that the stress varies as the ordinates of a parabola, and not as the ordinates of a straight line. On the other hand, I am inclined to doubt the statement of Considère that the concrete on the tension side can undergo an extension much greater than 0.02 per cent without cracking, when the beam is reinforced, whereas when not reinforced the concrete cracks when the extension is from 0.01 to 0.02 per cent. The mere fact that a reinforcing rod is present does not seem sufficient to change the physical properties of the concrete.

6 I believe Professor Turneaure has shown Considère to have been wrong in this assumption. It is not at all unlikely that Considère removed a piece of concrete in which no cracks had developed. Furthermore, if cracks are allowed to develop on the tension side—and this has frequently been observed in beams under working load—might not this crack gradually extend under repeated loading and seriously impair the safety of the structure?

B. H. Davis.[1] Certain practical considerations may be cited to

[1] Assistant Engineer, D. L. & W. R. R., Hoboken, N. J.

illustrate the difficulties confronting the experimenter seeking a rational solution of the deflection problem. Shrinkage is the worst, or perhaps the most indeterminate factor to be eliminated, since it spoils so many carefully performed experiments, being a large cause of the lack of uniformity so generally noted in experimental data.

2 The shrinkage of a concrete block 8 in. sq. by 2 ft. long has been shown to shorten appreciably a bar ½-in. square embedded in it and accurately measured before and after the setting of the concrete around it. This produces an initial tension in the concrete and an initial compression in the steel. In the case of a beam reinforced in only one plane, as perhaps some of the beams tested may have been, these initial strains may largely account for the lack of uniformity in the results obtained.

3 The shrinkage of concrete in setting, nearly always a variable factor, has almost completely upset the theory of arch-ring deflections when the arch centering is struck. Some settle very considerably upon striking the centering, especially when the arch ring is a monolith from skewback to skewback, while others settle hardly at all when alternate voussiors are made and allowed to set and shrink before the ring is keyed. Shrinkage, it has been proved, almost entirely causes this lack of agreement between the theoretical and the actual deflections when arch centers are struck. It would therefore seem logical to assume that the same cause figures prominently in the deflection phenomena of beams.

4 The shrinkage of a beam of large cross section, acting in opposition to that of a smaller beam, has been known to crack the weaker member from top to bottom, breaking up any dependence that might otherwise have been placed upon the concrete in tension, before the beam had been called upon even to support its own dead load.

5 In designing for a given load by the commonly accepted straight-line formulæ for obtaining stresses in steel and concrete, and using the prescribed unit stresses of the building code, a certain factor of safety results. In other words, an overload of two or three times the load assumed in the design, may be applied, and when removed, the structure should be just as capable of supporting the working load for which it was designed as before the overload was applied.

6 Now, granting the conclusion of the author, in Par. 27, that tension in the concrete materially affects the deflection and strength of beams (between certain limits of load), would it not still seem unwise to take advantage of this tension factor in any design where the assumed load limits might be overstepped at some time, leaving

the beam to serve the remainder of its period of usefulness without the tension factor counted upon in its design?

7 Almost every design is over-stressed sooner or later, occasionally by test load, but more often perhaps, because of the enthusiasm of some shop foreman in showing what his building will stand in the way of abuse. For example, loaded cars of gravel and broken stone, and later a 600-class standard-gage locomotive, were run across a machine and erecting shop floor that was designed for a uniformly distributed load of considerably less than one-half the concentrated moving loads applied, this without any apparent damage to the floor.

8 Settlement, which very often upsets carefully made calculations, causes even more indeterminate stresses in reinforced concrete than in other types of construction, this being due to the continuity and the monolithic character of the material. This fact further emphasizes the necessity for conservatism in working formulæ.

9 Construction joints, put in as they usually are, at points of maximum moment, make any reliance upon the concrete in tension entirely out of the question where such joints occur. It is not generally conceded that construction joints so located do materially weaken a beam except in shear.

10 A beam accidentally cracked entirely through near its middle, while being placed in a testing machine, tested higher than the average of several other beams of the same size and reinforcement, showing that a plane of fracture approximately normal to the center line of a beam had not, in this particular case, unfavorably affected the ultimate strength of a beam equally loaded at its third points.

11 Until more is definitely known concerning the shrinkage of concrete and the many other stresses in reinforced-concrete beams at present indeterminate as a matter of conservatism it would seem better to disregard tension in concrete as a moment-resisting factor.

Chas. B. Grady.[1] Professor Lanza and Mr. Smith have clearly brought out the fact that three of the formulae used for the design of reinforced-concrete beams are approximate with a load of one-third the breaking load. The writer will say a few words in reference to the use of these formulae in the design of beams.

2 Formulae A and B, which are used by a large number of engineers, do not allow anything for the tension in the concrete and therefore must give for rectangular beams results which are mere

[1] Asst. Mechanical Engineer, New York Edison Co.

approximations up to a point at which the concrete fails to act in tension, but the writer believes that if a comparison had been made at say double the load used, Formulae A and B would have given better results, and possibly nearer those found by actual test, than Formula C, especially for the value of σ_s (stress in steel per square inch).

3 In tests of similar beams made at Cornell University by Messrs. Paulus, Tripp and Davis, the average variation in the values of σ_s (stress in steel per square inch) deduced by formula A from those found by experiment was 34 per cent with a load of 4000 lb., and less than one per cent with a load of 8000 lb. The above figures are for five beams having an average breaking strength of 13,200 lb.

4 The errors in values deduced by Formulae A and B are more liable to be on the side of safety than the errors in values deduced by Formula C, and while there is no doubt that Formula C will give more accurate results when the stress in the steel is comparatively small, it is the opinion of the speaker that Formula C, and other formulae making allowance for the tension in concrete, should be used with caution.

5 It is the practice of many engineers to design reinforced-concrete beams in accordance with certain working stresses and to endeavor so to proportion the beam that it will fail by tension, that is, by either breaking or stressing the steel to a point considerably past its elastic limit, thus making the factor of safety a function of the stress in the steel. In such cases, no matter how much the concrete has helped out the steel under working conditions, when the beam is overloaded the steel must take care of practically the entire tension; and therefore the writer believes that it is wiser not to introduce a value for the tension in the concrete into the formulae used in the design of reinforced-concrete beams.

6 The speaker believes that the formulae for deflection deduced by Professor Lanza and Mr. Smith will be of great value to engineers, and that any one of the three formulae will give results accurate enough for practical purposes in figuring the deflections of T-beams, more of which are used in buildings than rectangular beams.

Frank B. Gilbreth. The most important subject related to reinforced concrete, from the standpoint of the mechanical engineer, is the design of forms, for it is the forms that afford the greatest opportunity for the saving of money, and the consequent reduction of price per cubic foot of new buildings.

2 Beams have been designed and built of rectangular section and over 64 ft. 0 in. long, and have beeen perfectly satisfactory. The most successful building of today as well as of the future must be designed with regard to the economical design and use of forms, and not to the greatest saving in the quantity of steel and concrete used. The forms are the most expensive single item of reinforced-concrete work, and a series of papers and discussions on economics of forms will be of more use to the members than any possible study of the savings that might come from refinements in the design of beams.

3 It is by no means rare to see designs for saving concrete where the value of the concrete saved amounts to much less than the cost of the special or odd-sized forms required.

Prof. Wm. H. Burr. Much has been said about the disagreement of theoretical results with the results of experiments. That is an observation which may be made, I believe, in the case of every material which has ever been used by the engineer; scarcely more so of concrete, either plain or reinforced, than of other material. When a comparison of this kind is made, I think we should bear in mind, first, what theory is used.

2 The so-called common theory of flexure probably is not strictly applicable to any reinforced-concrete beam which has been broken. It is a theory which applies to a beam of very small depth, compared with the length of span. This is not the kind of beam usually found either in plain or reinforced concrete, and usually not even in steel. It is not a matter of surprise, therefore, that such a theory does not give the results found by experiment.

3 It seems to me we shall have to proceed with reinforced-concrete beams precisely as with beams of other material, viz: use a simple working hypothesis for the purpose of securing a formula in which empirical quantities determined by experiment may be used. That is the case with wrought-iron and steel beams, with timber beams, and with all other beams, and it is markedly so, even to a greater extent, with columns.

4 The three theories, A, B and C, may be considered in view of the varying conditions at different stages of stress. It would be difficult to show from any results of tests of concrete, that the law of distribution of stress in theory B is justified. There are some tests which show a graphic relation between the intensities of stress and strain, which approximates a parabolic curve, but probably no nearer

than a circular curve or some other. The majority of tests show that line much more nearly straight than parabolic within the limits of stress found in ordinary concrete beams.

5 It is true that concrete has considerable tensile resistance, when it possesses any, but I think there are few engineers who have used much plain or reinforced concrete, who would be willing to trust the tensile part of the beam to carry load, and to be so recognized in the working formula.

6 The result of the slight contraction of concrete, possibly not within the first two months, perhaps not within the first year of its life, is to create fine hair cracks. We do not know how far these enter the mass; they may be only skin-deep, but in some cases they are much deeper. Hence if the beam should show a continuous concrete structure on the tension side for the first two or three months, it does not follow that it is going to remain so. If we are to recognize such a possibility, and it seems to me we would not be justified in neglecting it, the only safe procedure is that usually followed, of neglecting tension in concrete. That does not mean that concrete may not sometimes have considerable tensile resistance. It simply means that such resistance cannot safely be recognized in ordinary concrete work.

7 These cracks may be very much reduced by continual wetting of concrete after it has been put in place. That is one direction in which the concrete work may be improved. We do not wet the concrete nearly enough after the forms are taken away. If it were feasible, concrete should be kept thoroughly wet from three to six months after being put in place. This is not practicable; but after the forms are taken away, the concrete should be kept soaked with water just as long as possible. The contraction will be less and there will be fewer hair cracks, but it will be impossible to eliminate them entirely.

8 We should be sensible, as engineers, in connection with reinforced-concrete work, precisely as we are or ought to be in everything else, and use the simplest possible formula, i. e., the straight-line formula, and not strain after some ultra-refinement which, when we come to examine it, has little or no solid basis. We should resort to proper theories and select a simple working hypothesis, and then use the test beams to determine such empirical coefficients or quantities as will make the resulting formulæ represent actual results as nearly as possible.

Prof. J. C. Ostrup.[1] Within a short time, from fifteen to twenty years, at most, reinforced concrete has gained an enviable position in the construction world, and unquestionably, in spite of many inherent shortcomings, will better its reputation in the future among both engineers and laymen. It is, therefore, to be regretted that the trend of the authors' paper is toward a negative rather than a positive support.

2 It is a well-known fact that the greater number of the deductions and working formulæ obtained from the science of applied mechanics are based upon certain assumptions which to a greater or less, usually less, extent circumscribe the use of such formulæ. The errors resulting from these fundamental assumptions vary considerably with the different engineering materials with which we deal; they often vary considerably even with the same material, changing somewhat with the extreme fibre stress, the manner of application of the load, etc. The assumptions made in regard to the behavior of structural steel are probably nearer the absolute truth than for any other engineering materials, so near, in fact, that many engineers have come to regard the theory of steel design as following an unassailable mechanical law. Nevertheless this is not so.

3 On the other hand, the theory of reinforced concrete is based upon many assumptions, some of which can be better defended than others, and some of which have undergone, and will continue to undergo, modifications from time to time. It is also based upon many widely varying experiments which the experimenters themselves have been struggling to reconcile. Some of the most important of these assumptions, together with a brief account of their probable effect, are:

a That the applied forces in bending are perpendicular to the neutral axis.

4 This is incorrect, of course, inasmuch as the neutral axis under deflection follows a curve resembling a parabola. The resulting error is, however, extremely small.

b That a sectional plane, true before bending, also remains true after.

c That each fibre acts independently of adjacent fibres.

5 The last of these assumptions is particularly faulty, inasmuch as the ordinary reinforced beam usually has its reinforcement vary-

[1] Professor Structural Engineering, Stevens Institute of Technology.

ing in amount, both horizontally and vertically, throughout its length. In other words, unlike a rolled steel beam whose moment of resistance is uniform from end to end, the reinforced beam is not uniform in strength, the stronger parts tending to assist or restrain the weaker. The error from this assumption cannot be evaluated.

> *d* That the concrete and the reinforcement will stretch or compress together without breaking the contact bond between them.

6 This condition, when complied with, as it infallibly must be in all cases, unquestionably sets up secondary local stresses, the magnitude of which cannot be even guessed.

> *e* That there are no initial stresses.
> *f* That the stress-strain curve for compression is a parabola.

7 The fulfillment, or the non-fulfillment, of the last two assumptions, is probably what causes the greatest divergence between theory and tests. A concrete beam is a casting, in a sense. If the mixture were perfectly uniform throughout, there would most likely not be any initial stresses due to the chemical action of setting. This is evidently not possible; hence throughout the beam there undoubtedly exist initial stresses of uncertain magnitude. This fact, in itself, would surely affect the stress-strain curve, but in addition we must consider the variable modulus of elasticity for the concrete. This varies not only in the same beam, according to unit stress in the extreme fibres, but also in beams of the same identical composition according to its depth, i. e., to the relation between the extreme fibre stress and the average fibre stress.

8 In addition to these mechanical considerations, we have many physical considerations governing the strength of concrete and reinforced-concrete beams. Such physical conditions must largely depend upon the personal equation of the engineer in charge; they may be guarded against, and their effect minimized but not wholly eradicated. When present, their influence can only be surmised.

9 To make this a little clearer let us assume a case where a number of beams were to be prepared for a testing machine and where great uniformity naturally would be sought; to insure which, only one grade of cement, one of sand and one of broken stone, would be employed. Next let us look into some of the more important points affecting the strength of concrete, as follows:

a Condition of the cement; whether all the bags in a cargo are of the same age, or manufacturing batch; quantity of carbonic acid contained; degree of moisture (since the outside bags in a stack, and even the outside layer in the same bag, often absorb considerably more moisture than the inside).

b Uniformity of quality of the sand; whether or not it contains in spots, loam, clay or other impurities, etc.

c Uniformity of the broken stone; whether or not the stones are alike in strength and texture; whether or not they are broken to a uniform size, etc.

d Quality or purity of the water; method of mixing the concrete, or difference in methods of mixing from batch to batch, even by the same gang.

e Tamping and placing of the concrete, including the often unavoidable variations in the degree of flexibility of the support between the ends and the center of the beam while the concrete is being tamped.

f Workmanship. A man is not a machine, consequently the materials mixed and the beams made, even by the same gang, will often vary considerably in spite of precautions. May not beams vary much more when made by different sets of workmen?

10 Besides the foregoing points affecting the mechanical laws governing the strength of the concrete, there are others; but enough have been indicated here to show that, when tested, a variation in their strength must exist.

11 Since each experimenter must base his deductions upon the results of his own observations, a divergence in the resulting formulæ is the natural result, and furthermore, were he to repeat the same tests under similar circumstances, his second results, in view of the foregoing, would vary from his first. With all this in mind, is it any wonder that closer agreement between the various working formulæ most generally in use, has not so far been reached? To an unbiased mind the wonder is that the divergences are not even greater.

12 Returning to the conclusions of the author, he states in Par. 24 " . . . . the observations made thus far are not sufficient to furnish the means for determining the actual distribution of the stresses, and hence for the deduction of reliable formulæ . . etc." This may be strictly true in theory, but will hardly be generally accepted as a matter of fact. On the contrary, it is quite within

good reason and good practice to deduce reliable formulæ, even where the action of some of the minor points involved is in doubt, so long as the effective range of such points is known. In this connection it may be recalled that concrete and masonry structures, centuries old, are still standing and doing effective service, though they were designed from formulæ and data far less reliable than those now at our disposal.

13 The author further says: "It follows therefore that whichever of the theories is adopted for practical use, it can be regarded only as a sort of working hypothesis." This, of course, is a sweeping condemnatory statement which, if it can be applied to the theory of reinforced-concrete construction, can, it is believed, be equally well applied to the theories underlying any form of construction; for no amount of theory, unaccompanied by practical experience and sound judgment, will prevail, either in the mechanical or in any other engineering field. This fact cannot be too strongly emphasized.

14 In Par. 26 the author states that theory C gives results in closer agreement with experiments than does either A or B. This is undoubtedly true, but so far as the evidence in Tables 5 and 6 is concerned, any one of the three theories is based upon "reliable formulæ" or, what is more to the point, the designs resulting from their use would be wholly reliable. As a matter of opinion, the preference should be for A or B, since they are nearly correct in regard to the unit stresses in the concrete,—the weaker material,—whereas they give somewhat smaller stresses for the steel than those expected.

15 It is equally true that no reliable deflection formulæ can be deduced without taking into consideration the tension in the concrete. We can, however, go a step further, and state that such formulæ, to be correct, must also include a provision for a deflection increment due to shear.

16 In concluding these remarks, the writer would suggest a caution to such alarmists as are prone to appear from time to time against a useful and excellent building material. No public good can result from arousing the apprehension of either engineer or layman with respect to reinforced concrete, and those of us who have had the opportunity of using it for a number of years cannot help but be impressed with its increasing serviceability and scope.

E. Lee Heidenreich.[1] The tests at the Massachusetts Institute of Technology, as well as those at the University of Illinois, were based upon a concrete mixture of 1 : 3 : 6, while those of Considère

[1] Special Engineer, N. Y. C. & H. R. R., New York City.

are based upon a mixture of 1 : $2\frac{1}{2}$: $2\frac{1}{2}$. I have repeatedly at meetings of the "Joint Committee" urged the desirability of employing stronger mixtures, and mixtures of a "maximum density" rather than a certain proportion; and I believe that with such stronger mixtures Formula C will come still nearer to a correct interpretation of stresses and strains. If so, is it not natural to hope that in our reinforced-concrete building constructions, lesser dimensions of beams and girders, thinner floor slabs, and consequently a reduced item of *dead load* will result, also materially reducing the present disadvantages of heavy columns and foundations?

2 The most wonderful constructions of tanks, reservoirs and bridges in Europe, have resulted from mixtures of 1 : 3 or 1 : 5, properly graded. Why should not our beam tests be based upon such mixtures, notwithstanding the fact that at first glance they may not appear commercially advantageous for building constructions? I wish to place myself again on record as advocating a larger percentage of cement and a mixture representing a maximum density of the ingredients.

Prof. C. E. Houghton. The paper adds to our knowledge of the probable magnitude and sign of the errors due to the use of formulæ deduced from a simpler theory. When the size of a structural member has been calculated by the use of a formula known to give a greater value to the unit stress than actually exists, the designer need not worry about the safety of that member. If in addition the probable magnitude of the error is known, corrections may easily be made where it is considered necessary to reduce the cost or weight of the member.

2 The neglect of tensile resistance in calculations of the strength of reinforced-concrete beams finds a parallel in the common practice for the calculation of the strength of riveted joints. The friction between the plates unquestionably adds to the strength of the joint, yet as far as the writer knows, no theory has been accepted in American practice that considers this friction as acting. This friction, like the tensile resistance of concrete, may vary from zero to a maximum value, and therefore should be neglected, as neither can be depended on for additional strength.

3 All formulæ for the strength of reinforced-concrete beams contain a factor whose value is the ratio of the modulus of elasticity of steel to that of concrete, and any error made in the assumption of that value affects the result in the same proportion. The modulus of elasticity

of steel is practically a constant term, but that for concrete varies through a wide range of values depending to a certain extent on the proportions of cement, sand and broken stone used in the concrete.

4 With the large possible variation of this ratio in mind, it would seem reasonable to suppose that the probable error, either in assuming a straight-line law for the variation of the compressive stress in the concrete, or in the neglect of its tensile resistance, will be less than that due to the choice of the value of this ratio. What is needed is a value for this ratio, determined by applying the formula derived from the straight-line no-tension theory, to the results of a great many tests on specially prepared beams.

5 The number of variable conditions that would affect the results in any such investigation is so great that unless one of our national engineering societies will undertake it there seems to be but little prospect of obtaining anything more than an approximate value based on the results of compressive tests on concrete.

Wm. Wallace Christie. The writer is particularly interested in the applications of reinforced concrete in engineering work, and has had to do with the designing of a great many floors, foundations and other work. He agrees with Professor Burr, and others not prepared to accept or consider a theory of design of concrete-steel beams allowing tension in the concrete, or an increase by reinforcement of the ability of the concrete to resist tension.

2 After concrete work has been erected for a time, hair-cracks, and others more decided, often develop in the beams. An example of this has already been cited: a 70 ft. concrete girder, or longer, with its center, at least, resting on hard pine timbers.

3 With the large factor of safety necessary in the design of concrete-steel beams, one cannot go very far wrong in using any of the three methods mentioned, but the writer prefers a straight-line formula.

4 The paper deals in particular with beams, which in practice are seldom used, except as lintels, or over openings in building walls. The experiments conducted with these beams will not give the results obtainable by the use of T-beams, and the writer doubts whether the test of a single T-beam, made in the test room, will develop the same strength or other features, as a test made on a similar T-beam which is part of a floor system. The beam tested in the laboratory is not joined tightly with the rest of the floor, while in actual construction the iron would necessarily be secured to the other parts of the floor system.

THE AUTHORS. The data and the results of observation for the first five beams, which have been asked for, are contained in a paper by G. Lanza, published in the proceedings of The American Society for Testing Materials for 1906.

2 The modulus of elasticity of the concrete was obtained from tests made upon seven 8 in. by 8 in. by 60 in. plain compression pieces of the same age, materials and mixture as the beams. The values of E are as follows:

	2,479,000
	2,223,000
	2,367,000
	2,264,000
	2,670,000
	2,623,000
	2,341,000
Average	2,424,000

In our paper we have used 2,335000 in order to permit of the use of $r = 12$.

3 It may be added that the neutral axis was determined for each load from the strain diagrams (which are shown graphically in the paper referred to) at the intersection of the plotted line with the vertical datum line. Numerical details of the strains will be given in appendix A, as they seem to be desired.

4 As reference has been made to evidence tending to discredit Considère's theory regarding the ability of concrete to stretch when reinforced, it may be well to say that it is neither the object of the paper to discuss this question, nor to take sides for or against this theory. The history of the main part of the controversy is as follows:

5 The theory was attacked by Kleinlogel in an article published in Beton u Eisen, Hefts 2 and 4, 1904, in the light of certain tests which he had made. The two tests of Considère on page 1038 of our paper were made as a refutation of Kleinlogel's argument. An account of them may be found in Considère's book on reinforced concrete. A subsequent reply by Kleinlogel, and a reply to this by Considère, are to be found in Beton u Eisen, but no new matter is given.

6 In Beton u Eisen, Heft 11–1905, Professor Ostenfeld gives an account of the results of some computations made by him upon the beams tested by Kleinlogel, and in the light of these he says "Thus

far I regard Kleinlogel's tests as a beautiful though unwilling confirmation of Considère's theory." To this Kleinlogel replies in Beton u Eisen, Heft 1-1906, but this reply contains no new evidence.

7 Fear seems to be expressed by some that pointing out the very considerable discrepancies between the results of computation made by theory *A*, and the results obtained by experiment, is equivalent to a condemnation of all structures where theory *A* was used in the computations. No such condemnation, however, is intended by the authors. They believe, however, that the more we realize the facts in any case, the better prepared are we to use our judgment as engineers, in designing any construction.

8 Most of the arguments advanced in support of the entire sufficiency of theory *A* may be summarized as follows:

a The calculations can be more easily made.

b That the mere fact of neglecting the tension in the concrete results in safety, though practically all admit that the concrete does resist tension in the early stages.

c The use of construction joints, which often take the form of a vertical joint at the middle of the span when work on a given floor extends over a period greater than one day.

9 These matters will be considered in the same order:

a There is no doubt that the calculations are more easily made when theory *A* is used.

b Whichever of the three theories is used, it is not customary to calculate by means of it, the stresses which produce diagonal cracks, and it is a fact that in a very large percentage of the beams that have been tested, the failure has been due to these diagonal cracks. Hence it seems to us that until we have arrived at some means of making calculations to determine these stresses and strains in such a way that the calculated results shall have a fair degree of agreement with the results obtained by experiment, we can hardly claim to have an all-sufficient theory. Moreover, in the case of beam A-1, the only one for which the shear has been figured, it is greater when determined from theory *C* than when obtained from theory *A*, the difference being in one case 57 per cent.

c When a construction joint is introduced, the beam is necessarily weak, and until tests of such beams are made, we cannot claim to know what theory will apply to them.

10 Other considerations which it would seem worth while to discuss are the following:

a The presence of initial stresses due to shrinkage.

b The variation in the value of the compressive modulus of elasticity of concrete.

c The recommendation made by some that the formulæ to be used be based upon loads larger than one-third the breaking load, and by some upon the breaking load.

d The question of so proportioning the reinforcement that the breaking shall be due to the tension in the steel exceeding the elastic limit.

11 Discussing these in order we have:

a The presence of initial stress is of course a great source of uncertainty in reinforced concrete, as well as in cast iron, and hence we should expect irregularities due to this cause, the amounts of which are very difficult to estimate. Whether their influence is still large or not at one-third the breaking load, is a debatable question, though it must be comparatively less at one-third than at smaller loads. On the other hand, with loads greater than one-third the ultimate, the ratio of stress to strain becomes quite variable, and any rational formula becomes inaccurate.

b In the light of the experiments made by different men and in different places, it would seem to the authors that the variations of the modulus of elasticity for compressive stresses in the concrete, not more than one-third the ultimate, would not be very excessive.

c In the case of steel or other beams it is well known that the ordinary formulæ do not apply when the stresses in any of the fibres have passed the elastic limit; hence the difference between modulus of rupture and outside fibre stress at breaking.

d Regarding the question whether theory *A* will agree better with experiment when the percentage of reinforcement is kept so low that the elastic limit in the steel will be exceeded before any fibre of the concrete has to bear a stress equal to its crushing strength, the only evidence in the paper is the following: In one case the percentage of reinforcement was as low as 0.99 per cent, and in three others, 1.25 per cent, and in these three cases the discrepancies of theory *A* are large.

12 In general, it seems to us that thus far not enough systematic work has been done by way of experimenting and calculating in order that we may have more accurate knowledge about a number of matters, among which may be mentioned:

a The actual distribution of stresses not merely in the case of longitudinal reinforcement, but also with diagonal and other reinforcements, and also in T beams.

b A study of the diagonal tension, not only at the neutral axis, but elsewhere.

c A study of the conditions necessary that the breakage may always be due to the reinforcement exceeding the elastic limit, and whether diagonal cracks occur in those cases.

d A study of the effect of construction joints.

13 There only remain for discussion a few additional matters raised by different gentlemen. While it appears from the last column of Mr. Worcester's table that method *C* gives average results on the negative side, it must be remembered that they depend upon the value taken for *t* (the tensile strength of the mixture). This table, as well as Table 5, clearly shows that if a slightly lower value of *t* had been used for these six beams, their average error would have been a positive one, and also smaller than that by using *A*.

14 Replying to the question of Mr. Newman, we do not think the discussion of the Bethlehem beams is sufficiently relevant to the matter of this paper to be taken up here.

APPENDIX A

STRAINS FOR THE M. I T. BEAMS.

The strains were measured at four points in the depth of the beam on each side as described in the paper before the American Society for Testing Materials, already referred to. Columns 1, 3, 4, 2, in the following tables give the strains for these points. Points 3 and 1 were one and five inches, respectively, *above* the center of the beam, while points 4 and 2 were one and five inches, respectively, *below* the center.

BEAM A-1

ONE 1-INCH PLAIN ROD. AGE 53 DAYS.
INITIAL LOAD 1250 LB. BREAKING LOAD 15000 LB.

Loads Lb.	Strains 1	3	4	2
2250	0.000023	−0.000008	0.000033	0.000060
3250	0.000064	−0.000009	0.000048	0.000108
4250	0.000107	0.000008	0.000057	0.000195
5250	0.000186	0.000022	0.000071	0.000262
6250	0.000228	0.000009	0.000124	0.000352
8250	0.000345	0.000005	0.000186	0.000569
10250	0.000448	−0.000022	0.000274	0.000795
12250	0.000543	−0.000026	0.000337	0.001017
14250	0.000672	−0.000088	0.000466	0.001279

BEAM A-2 FIRST APPLICATION

ONE 1-INCH TWISTED ROD. AGE 49 DAYS
INITIAL LOAD 1250 LB. BREAKING LOAD 16500 LB.

Loads Lb.	Strains 1	3	4	2
2250	0.000044	0.000012	0.000003	0.000033
3250	0.000082	0.000012	0.000027	0.000093
4250	0.000138	−0.000013	0.000077	0.000174
5250	0.000172	0.000016	0.000073	0.000251
6250	0.000216	0.000018	0.000108	0.000358
8250	0.000317	−0.000004	0.000202	0.000595
10250	0.000405	−0.000009	0.000271	0.000835
12250	0.000505	−0.000063	0.000391	0.001039

BEAM B-3

TWO ¾ IN. PLAIN RODS. AGE 43 DAYS.
INITIAL LOAD 1250 LB. BREAKING LOAD 15950 LB.

Load Lb.	Strains. 1st application 1	3	4	2
2250	0.000073	0.000013	0.000017	0.000081
4500	0.000100	−0.000003	0.000059	0.000175
5250	0.000144	0.000015	0.000060	0.000223
6250	0.000195	0.000002	0.000096	0.000289
8250	0.000398	−0.000020	0.000182	0.000428
10250	0.000519	−0.000066	0.000301	0.000587

BEAM C-5

FOUR ½ INCH PLAIN RODS. AGE 35 DAYS
INITIAL LOAD 600 LB. BREAKING LOAD 16240 LB.

Loads	Strains			
Lb.	1	3	4	2
2600	0.000083	0.000018	0.000026	0.000087
4600	0.000219	−0.000024	0.000133	0.000296
6600	0.000337	−0.000067	0.000239	0.000532
8600	0.000444	−0.000059	0.000297	0.000751
10600	0.000542	−0.000091	0.000406	0.001023
12600	0.000631	−0.000137	0.000525	0.001272
14600	0.000765	−0.000209	0.000653	0.001525

BEAM E-9 FIRST APPLICATION

TWO ⅜ IN. TWISTED RODS AGE 54 DAYS
INITIAL LOAD 1250 LB. BREAKING LOAD 21000 LB.

Load	Strains			
Lb.	1	3	4	2
2250	0.000037	−0.000012	0.000029	0.000037
4250	0.000107	0.000003	0.000046	0.000134
5250	0.000155	0.000008	0.000060	0.000175
6250	0.000202	0.000004	0.000081	0.000256
8250	0.000275	0.000004	0.000122	0.000402
10250	0.000403	0.000010	0.000161	0.000541
12250	0.000486	0.000003	0.000212	0.000680

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Instructions for Reforesting Land. By C. R. Pettis. *Albany, N. Y.*, 1909.

Life of Robert Fulton. By his friend, C. D. Colden. *New York*, 1817.

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The Monist. Complete Index to Vol. 1–22. 1890–1907. *Chicago*, 1908.

New Complete Dictionary of the English and Dutch Languages. Two Parts. Ed. 2. By I. M. Calisch. *Tiel*, 1890, 1892.

One Hundred Ton Modern Cyanide Plant. By C. C. Christensen. (In *Mining World*, Nov. 13, 1909.)

Present Aspect of Electric Lighting. By H. W. Handcock and A. H. Dykes. Institution of Electrical Engineers, August 1909. Gift of Calvin W. Rice.

Prevention of Industrial Accidents. No. 1—General. *New York*, 1909. Gift of Fidelity & Casualty Co.

Report of the Tests of Metals and Other Materials, 1908. *Washington*, 1909.

Sierra and San Francisco Power Company. Stanislaus Power Development. Reprint from Journal of Electricity, Aug. 21, 1909.

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Status of the Engineering Profession. By G. A. Thomas. *London*, 1909. Gift of Society of Engineers.

Sur le Choix de l'Obliquité de la Ligne d'Engrenement pour les Engrenages a développante Considérations Théoriques et Pratiques. By Edmond Dubosc. (Extract from La Revue de Mécanique, 1903.) *Paris*, 1903.

Technique du Ballon. By G. Espitallier. *Paris*, 1907.

Technischer Verein von Philadelphia. Statuten und Nebengesetze, 1907. *Philadelphia*, 1907.

Théorie des Déraillements Profil des Bandages. By G. Marié. *Paris*, 1909. Gift of Dunod & Pinat.

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Utilization of Fuel in Locomotive Practice. (Bulletin No. 402, U. S. Geological Survey.) By W. F. M. Goss. *Washington, Govt.*, 1909.

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EXCHANGES

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Applications of Electricity to Propulsion of Naval Vessels. By W. L. R. Emmet. Society of Naval Architects and Marine Engineers. November 1909.

Building and Equipping the Non-Magnetic Auxiliary Yacht *Carnegie* with Producer Gas Propelling Equipment. By W. Downey. Society of Naval Architects and Marine Engineers, November 1909.

Development of the Gasoline Power Boat. By E. T. Keyser. Society of Naval Architects and Marine Engineers, November 1909.

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Material for Handling Equipments for Lake Vessels. By R. B. Sheridan. Society of Naval Architects and Marine Engineers, November 1909.

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Strength of Water Tight Bulkheads. By W. Hovgaard. Society of Naval Architects and Marine Engineers, November 1909.

Structural Rules for Ships. By James Donald. Society of Naval Architects and Marine Engineers, November 1909.

System of Mathematical Lines for Ships. By J. N. Warrington. Society of Naval Architects and Marine Engineers, November 1909.

TRADE CATALOGUES

E. W. Bliss Co., *Brooklyn, N. Y.* Steam turbines, direct connected to generators, blowers, pumps. 10 pp.

Celfor Tool Co., *Chicago, Ill.* Drills, reamers, chucks, and grinding machinery. 29 pp.

George N. Cole, *New York, N. Y.* Cross horizontal folding doors, "Canopy" and "Jack Knife" construction. 18 pp.

William Cramp & Sons Ship and Engine Building Co., *Philadelphia, Pa.* Automobile and Motor boat castings, 45 pp.; Parsons' white brass ingots and manganese bronze ingots, 24 pp.; Propellers for motor boats, 19 pp.; Parsons' white brass, 8 pp.; Dimensions and price list of Parsons' manganese bronze rolled sheets and rods, 10 pp.

Darley Engineering Co., *New York, N. Y.* Bulletin No. 4. Suction conveyor for coal and ashes. 16 pp.

Diamond Power Specialty Co., *Detroit, Mich.* Pamphlet No. 5: Economical production of steam. 8 pp.

Diehl Mfg. Co., *Elizabethport, N. J.* Bulletin No. 102 on type G motors and generators for general power purposes, 10 pp.; bulletin No. 151 on types F and FC motors and generators. 16 pp.

Dodge Coal Storage Co., *Philadelphia, Pa.* Handling and storing coal and ore, 112 pp.; Telpherage, an electrically operated system of transporting material, 60 pp.; Coal storage according to the Dodge System, 55 pp.

Flinchbaugh Mfg. Co., *York, Pa.* Catalogue 9B: York gas, producer gas, gasoline, kerosene and alcohol engines, 48 pp.

General Electric Co., *Schenectady, N. Y.* Tungsten automobile electric lamps, 15 pp.; train lighting with G. E. Tungsten and Tantalum lamps, 5 pp.; Bulletin No. 4702: fire boats of New York, Chicago, San Francisco, etc., 16 pp.

Glasgow Iron Co., *Pottstown, Pa.* Iron and steel plates, muck bars, flanged and pressed work. 94 pp.

Industrial Instrument Co., *Foxboro, Mass.* Foxboro Recorder, November 1909. 16 pp.

Jenkins Bros., *New York.* Jenkins '96 packing. 1 p.

R. K. LeBlond Machine Tool Co., *Cincinnati, O.* Cutter and tool grinders. 40 pp.

Lyon Metallic Manufacturing Co., *Aurora, Ill.* Installation of Lyon Steel Factory Equipment in the George N. Pierce Co.'s Plant at Buffalo. 20 pp.

Magnolia Metal Co., *New York, N. Y.* Anti-friction metal, 10 pp.; Metal used as babbitt, 8 pp.; Metal vs. Genuine (tin) babbitt, 24 pp.

Northern Engineering Works, *Detroit, Mich.* Newten Cupola, with a differential, adjustable tuyere system and an all steel air chamber. 12 pp

W. R. Ostrander Co., *New York, N. Y.* Speaking-tube hardware, electric bells and batteries, electric light material, telephone and telegraph instruments, and general electric supplies. 690 pp.

Robbins & Myers Co., *Springfield, O.* Standard motors and generators. 32 pp.

M. Rumely Co., *La Porte, Ind.* Oil pull tractor for plowing, hulling, and threshing. 18 pp.

Sawyer Tool Mfg. Co., *Fitchburg, Mass.* Price list of machinists' tools. 55 pp.

Scully Steel & Iron Co., *Chicago, Ill.* November 1909 stock list of iron and steel supplies 96 pp.

Seneca Falls Mfg. Co., *Seneca Falls, N. Y.* Catalogue 22-B: screw cutting lathes, speed lathes and wood turning lathes and attachments. 36 pp.

Société des Ateliers Dubosc, *Turin, Italy.* Automatic machine for cutting conical gears, without pattern. 10 pp.

M. Steiner & Co., *Dayton, O.* Steiner gas and gasolene engines. 24 pp.

Stewart Heater Co., *Buffalo, N. Y.* Otis tubular feed water heater, oil separator and purifier. 16 pp.

Charles A. Stickney Co., *St. Paul, Minn.* Power pump feed, and gravity feed engines, 32 pp.; Bulletin No. 1137, 16 pp.

Joseph H. Wallace & Co., *New York, N. Y.* Representative industrial plants in the pulp and paper industries, and power plants. 200 pp.

Westinghouse Electric & Mfg. Co., *Pittsburg, Pa.* Circular 1094: Turbo-generator sets, 39 pp.; Circular 1103: Multiple arc lamps, direct current, 11 pp.; Circular 1177: Materials for switchboard panels, 11 pp.; Circular 1181: Portable direct current Ammeters and Voltmeters, 7 pp.

Williamson Submarine Corporation, *Norfolk, Va.* October 1909 Submarine Bulletin. 3 pp.

Wm. H. Wood, *Media, Del. Co., Pa.* Hydraulic machinery, 55 pp.; Loco fire box and tube plates, 16 pp.

UNITED ENGINEERING SOCIETY

Gift of J. McAllister Stevenson, Jr. and Louis T. Stevenson

Baker, T. Treatise on the Mathematical Theory of the Steam Engine. *London, 1864.*

Bennett, F. M. Steam Navy of the United States. *Pittsburgh, 1896.*

Bourne, John. Handbook of the Steam Engine. *New York, 1865.*

Haupt, Herman General Theory of Bridge Construction. *New York, 1866.*

Nason, H. B. Manual of Qualitative Blowpipe Analysis. *Philadelphia, Pa., 1881.*

Nystrom, J. W. Technological Education and the Construction of Ships and Screw Propellers, for Naval and Marine Engineers. Ed. 2. *Philadelphia, 1866.*

Perry, M. C. United States Japan Exhibition. Vol. 1–3. *Washington, 1856.*

Turnbull, John. Short Treatise on the Compound Engine. *Glasgow, 1873.*

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U. S. Navy Department. Report of the Secretary. 1867, 1873, 1876, 1880, 1885. Vol. 1. 1887. *Washington, 1867, 1873, 1876, 1880, 1885, 1887.*

U. S. Navy Department, Office of Naval Intelligence. Annual, July 1892. *Washington, 1892.*

Ward, J. H. Elementary Instruction in Naval Ordnance and Gunnery. *New York, 1861.*

Gift of Prof. F. W. Hutton

International Exposition, St. Louis, 1904. Official Catalogue. Exhibition of the German Empire. *Berlin.*

TRADE CATALOGUES

American Machine Company, *Louisville, Ky.* Full magnet control electric elevators for passenger and freight service, 14 pp.; Description of ammonia regulator for refrigerating machines, 2 pp.; Description of dehydrator for ice and refrigeration machines, 2 pp.; Absorption system of ice making compared with the compression system, 2 pp.; Catalogue of ice and refrigerating machinery absorption system, 37 pp.

Vilter Manufacturing Co., *Milwaukee, Wis.* Catalogue A: Refrigerating and ice making machinery. July 1909; Catalogue F: Ammonia fittings for refrigerating and ice making plants; Partial list of users of improved ice making and refrigerating machinery. April 1909.

COMMENT ON CURRENT BOOKS

Large Gas Engines. By Percy R. Allen. Reprinted from Cassier's Magazine, 1909. Cloth, 7 by 9½; 61 pages; 22 illustrations.

The author has divided his subject into three parts: the four-cycle engine—British and Continental practice; the four-cycle engine—American practice; and two-cycle engines. He has described the characteristics of each type at some length, numerous illustrations showing assembled engines and details of construction.

Cyrus Hall McCormick, His Life and Work. By Herbert N. Casson. *A. C. McClurg & Co., Chicago,* 1909. Cloth, 5½ by 8; xii + 264 pages; illustrated. Price $1.50.

The author is well known to readers of popular periodicals through his serials on The Romance of Steel and The Romance of the Reaper. In the present volume he has told of the early struggles and final success of the man who gave grain culture a wonderful impetus through his development of the reaper.

CONTENTS by chapter headings: The World's Need of a Reaper; The McCormick Home; The Invention of the Reaper; Sixteen Years of Pioneering; The Building of the Reaper Business; The Struggle to Protect Patents; The Evolution of the Reaper; The Conquest of Europe; McCormick as a Manufacturer; Cyrus H. McCormick as a Man; The Reaper and the Nation; The Reaper and the World; Give us this Day our Daily Bread.

Steam Navigation, a Chronological History of its Origin and Development. By George Henry Preble, Rear-Admiral, U. S. N. Second Edition. *L. R. Hamersly & Co., Philadelphia, 1895.* Half morocco, 6½ by 9½; 418 pages.

The author starts with the first recorded steamboat experiment in 1543, at Barcelona, Spain, and continues his narrative up to the year 1882, the time of writing. The matter is arranged chronologically, the dates being placed as side heads, so that reference to the development in any year is easily made. The author has treated his subject in an interesting manner, incorporating something of an anecdotal quality to appeal to the lay reader. The fact that the author spent twenty-five years in collecting his material, speaks for its value as an engineering record.

Morrison's Spring Tables. By Egbert R. Morrison. Published by the author at Sharon, Pa. Cloth, 6 by 9; 84 pages. Price $2.

The author has presented a comprehensive list of formulae and tables for the design of light and heavy helical springs and sheet and plate elliptical springs. The properties of light helical springs have been arranged under graduated values of the fundamental ratio—the ratio of the diameter of the bar (or similar dimen-

sion in other than circular sections) to the mean diameter of the spring. The properties of heavy springs are tabulated under each size of bar or plate. From a table on rectangular and elliptical sections, used in connection with the other tables on helical springs, the properties of such springs may be determined easily by proportion. For helical springs the working basis has been taken as one inch of solid height, and for elliptical springs a plate one inch wide. Calculations are based on a fiber strain of 80,000 lb. per sq. in. The modulus of elasticity is taken as 12,600,000 for helical springs and 25,400,000 for elliptical springs.

CONTENTS: Part I, Formulæ: Notation; Helical, Round Bar, Single Coil, General; Helical, Rectangular Bar, Single Coil, General; Helical, Round Bar, Single Coil, Steel; Helical, Rectangular Bar, Single Coil, Steel; Helical, Concentric Coils; Elliptical, General; Elliptical, Steel. Part II, Mathematical Tables: Fractional Parts of π; Cubes; Fifth Powers. Part III, Spring Tables: Helical Wire, Light Steel Spring Table; Helical, Bar, Machinery and Railroad, Heavy Steel Spring Table, Helical, Rectangular and Elliptical Sections; Elliptical, Sheet, Light Steel Spring Table; Elliptical, Bar Carriage, Medium Weight Steel Spring Table; Elliptical, Plate, Machinery and Railroad Heavy Steel Spring Table; Elliptical, Take-up.

MECHANIC'S AND MACHINIST'S POCKET BOOK. Edited by Wm. H. Fowler. Second Edition. *Scientific Publishing Co., Manchester, England, 1909.* Cloth, 4 by 6, 448 pages, illustrated. Price 6d.

This information in this book is largely culled from British practice, though the editor has in some cases incorporated data obtained from the United States. This is particularly true of the chapter on gearing, the most extensive section of the book. The chapter on shop practice deals with a variety of subjects such as the tempering and working of metals, pattern making, allowances for fits, and the like. A diary for 1910 forms an appendix to the book.

CONTENTS: Handy References and Tables; Mensuration, Geometry, and Trigonometry; Use of Logarithms and Antilogarithms; Materials Used in Machine Construction; Machine Tool Design; Proportions of Machine Tool Parts; Metal Cutting Tools; High Speed Tool Steels; Drilling and Boring Metal; Screw Threads, Screw Cutting, and Taper Turning; Emery and Emery Wheels; Shop Practice; Wheel Gearing; Belt and Rope Driving, Shafting; Lifting Ropes and Chains.

THE PREVENTION OF INDUSTRIAL ACCIDENTS. By Frank E. Law, M.E., and William Newell, A.B., M.E. *Fidelity and Casualty Company of New York, New York.* Paper, 5 by 8; 194 pages; 72 illustrations. Price 25 cents.

The prevention of industrial accidents has been the subject of more than one address, and New York has now a museum exhibiting safety devices for the protection of life and limb, but no literature in book form on the subject has yet appeared, we believe, except the book before us. The information was largely supplied from the company's own experience, but other sources—books, technical journals and trade literature—have also been drawn upon. Those features of boiler, engine and elevator design and operation, which must be carefully considered from the standpoint of preventing accidents, are treated at some length, while the safeguarding of the operatives, in factories in general and those of wood-working machinery in particular, is also considered.

CONTENTS by chapter headings: Introduction; Care on the Part of Employers and Employee;-Safety Devices; Steam Boilers; Engines; Electrical Apparatus; Elevators; The Factory; Wood-Working Machinery.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

01 Assistant professorship, in charge of design courses in engines, steam turbines, locomotive or gas engines, with assured advancement to full professorship in few years, for the right man. Institution desirous of having its men do outside work. Want a man of ability and experience. Position would pay initially from $1800 to $2000. Location, New York State.

02 A young technical graduate to carry out a series of brick-testing experiments. Previous experience not necessary. Work to last about one year with opportunity to continue on other work when brick testing is completed.

03 Technical graduate to act as general utility man in testing department of large steel works. Previous experience not necessary.

04 Designer of steam engines, compressors, etc., more especially accurate detailing for economic shop production. Position will pay about $2500. Location, New York.

05 Good opportunity is offered to a man with $15,000 to $25,000 capital, to join in an enterprise with a member who has a wide practical experience in manufacturing an electrical material for which there is an established and increasing demand.

06 Wanted, competent, practical operating engineer as chief engineer refrigerating plant of the Panama Railroad, Cristobal, Isthmus of Panama; experience with both refrigerating and electrical machinery essential. Good pay and quarters furnished. Exceptional opportunity for efficient man.

07 Mechanical Engineer to act as salesman for pipe and boiler covering materials; must be a good mixer without being a spendthrift. Salary $1500 to $1800 to start. Location New York.

MEN AVAILABLE

1 Technical graduate, Member, ten years engineering and sales experience, now employed as sales engineer, desires position in purchasing or sales department. New York.

2 Junior, graduate mechanical engineer, four years' experience design and installation; some experience with small gray-iron foundry.

3 Member, age 34, technical graduate, having experience in machine shop, drafting room, testing, estimating and office. Will consider position as manager of sales, or commercial position requiring a knowledge of machinery or engineering.

4 Graduate Lehigh University, class 1897, twelve years' experience as chief draftsman, designing engineer, mechanical engineer and superintendent. Automatic machinery and particularly that relating to printing and typewriting. Inventive and executive ability. Can handle men and take complete charge of the creation and manufacture of mechanical propositions and especially the development of new projects. Location, vicinity of New York.

5 Experienced designer of sugar machinery, in charge of drawing office, would like engagement with well-known manufacturers, as draftsman or erector; or would accept position as engineer in refinery or on plantation.

6 Member, past ten years chief engineer of complete design and construction of crushing plants, power plants, etc., past eight years entirely given to the design and construction of complete portland cement plants. Can furnish references to satisfy the most critical.

7 Mechanical and structural engineer with experience on furnace and mill design, buildings and general machinery, would like position as engineer or chief draftsman.

8 Mechanical and electrical engineer, at present employed as assistant to general superintendent, desires position as superintendent or engineer with concern manufacturing light or medium-weight machinery, or on engineering contract work. Long experience in both engineering and executive positions.

9 Specialist in steam turbine design, desires to locate with firm building steam or electrical machinery and contemplating the addition to present product of a line of steam turbines.

10 Graduate mechanical and electrical courses, W. P. I., age thirty-one, desires position in engineering or executive capacity. Experienced in engineering-contracting business, and construction; has installed, repaired and operated various types of gas, steam and electrical power equipment. Competent to prepare plans, specifications, estimates and reports. Six years on the Pacific coast and previously in New England. Salary $2500. Location immaterial.

11 Superintendent and manager desires change for larger opportunity; high grade organizer and executive; specialist on equipment, production and costs.

12 Shop manager and mechanical engineer; eighteen years experience in the design, manufacture and installation of heavy steam machinery, including hoisting and blowing engines, compressors, steam and hydraulic turbines. Eleven years in charge of factory operation. Best references.

13 Member desires position as works manager or general superintendent; twenty-four years experience as foreman, superintendent and manager of engineering works manufacturing high-class steam engines, boilers, air compressors and steam pumps; also cement mills. Good organizer and executive. If necessary prepared to invest in the right concern. West or Pacific Coast preferred.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALEXANDER, Ludwell Brooke (Junior, 1905), V. P., Haggerty Contr. Co., Davidson Ave. and Fordham Rd., and *for mail*, The Hazelhurst, 181st St. and Ft. Washington Ave., New York, N. Y.

APPLETON, Thomas (1893), Supt. of Constr., U. S. Public Bldgs., Alton, Ill.

AUSTIN, Adolph Odell (Junior, 1905), Asst. Engr., Vilter Mfg. Co., Milwaukee, Wis.

BAKER, Charles H. (Junior, 1903), 10 Relay Pl., Stamford, Conn.

BALDWIN, Abram T. (1899; 1902), Life Member; Solvay Process Co., and *for mail*, 689 Jefferson Ave., Detroit, Mich.

BARTH, Carl G. (1898), Cons. Engr., 1937 N. 33d St., Philadelphia, Pa.

BENET, Laurence V. (1892), Administrateur-Directeur, Société Anonyme des Anciens Établissements Hotchkiss & Cie, 21, Rue Royale, and *for mail*, 1, Ave. de Camoens, Paris, France.

BRANDON, Geo. Russell (1897; 1901), Harvey, Ill.

BRUSH, Frederick F. (Junior, 1900), Earlimart, Cal.

COLLETT, S. D. (1902), V. P. and Eastern Mgr., Elev. Supply & Repair Co., 114 Liberty St., New York, and *for mail*, 365 Sterling Pl., Brooklyn, N.Y.

CONRAD, Hugh Vincent (1887; 1891), Westinghouse Air Brake Co., Wilmerding, Pa.

GRIESS, Justin, Jr. (1898; Associate, 1908), Treas. and Sales Mgr., Interstate Engrg. Co., Builders Exchange, O.

HARRIS, Grenville A. (1907), Ch. Eng. Takata & Co., 50 Church St., New York, N. Y., and 176 Stiles St., Elizabeth, N. J.

HARTNESS, R. B. (Associate, 1903), 515 W. 124th St., New York, N. Y.

HEALD, Geo. W. (Junior, 1899), 7546 Eggleston Ave., Chicago, Ill.

HEALY, Frederick E. (1906), Mech. Engr. and Spec. Agt., Alberene Stone Co., and *for mail*, 415 3d St. N. W., Washington, D. C.

HECKER, H. A. (1906), 2032 Elm Ave., Norwood, O.

HUSSEY, Charles W. (Junior, 1908), 33 St. Andrews Pl., Yonkers, N. Y.

HYDE, Chas. E. (1885), 940 Fox St., Bronx, New York, N. Y.

LAVERY, Geo. L. (1886), Pres., Amer. Bank Equipment Co., 1315 Old Colony Bldg., and 4300 Ellis Ave., Chicago, Ill.

McCLATCHEY, A. F. (1889), 132 N. 4th St., Aurora, Ill.

McGEORGE, John (1891), Cleveland Engrg. Co., Cons. Engrs., New England Bldg., Cleveland, O.

MAHL, F. W. (Junior, 1892), Asst. to Dir. Maintenance and Operation, Union Pacific System and Southern Pacific Co., 135 Adams St., Chicago, and *for mail*, 1019 Michigan Ave., Evanston, Ill.

MILNE, James (1907), Cons. Engr., 304 Loo Bldg., Vancouver, B. C.

MONROE, Wm. Stanton (1896; 1901), Mech. Engr., Sargent & Lundy, 1720 Ry. Exchange Bldg., and 1235 N. State St., Chicago, Ill.

MORSE, Everett Fleet (1901), Morse Thermo Gage Co., 208 E. State St., and 111 Eddy St., Ithaca, N. Y.

NICKLIN, Ernest W. (1900; Associate, 1907), Mech. Engr., Detroit Brass Wks., and *for mail*, 421 Cadillac Blvd., Detroit, Mich.

PERRY, Wm. A. (1880), 1 Nassau St., and *for mail*, 7 E. 56th St., New York, N. Y.

ROWE, George F. (1908), 57 Penobscot St., Bangor, Me.

ROYLE, Vernon Elmer (Junior, 1905), Mech. Engr., John Royle & Sons, and *for mail*, 823 E. 28th St., Paterson, N. J.

SAMPLE, Morris De F. (Junior, 1905), Secy-Treas., Fire Protection Co., and *for mail*, 2901 Washington Blvd., Indianapolis, Ind.

SLEE, Norman S. (Junior, 1909), Engr. and Draftsman, Babcock & Wilcox Co., and *for mail*, 410 W. Park Ave., Barberton, O.

SMITH, Orin G. (Junior, 1899), Platt Iron Wks., 1224 Chemical Bldg., St. Louis, Mo.

SMITH, Otto T. R. (1906), Asst. Engr., Engrg. Dept., Otis Elev. Co., 17 Battery Pl., and *for mail*, 880 St. Nicholas Ave., New York, N. Y.

SORNBERGER, Edwin C. (1890), Allis-Chalmers Co., Ellicott Sq., and *for mail*, 208 Lancaster Ave., Buffalo, N. Y.

SWEET, Franklin (Junior, 1903), 285 Farwell Ave., Milwaukee, Wis.

THOMPSON, Edward P. (1884), M. E., Registered Pat. Atty., 1371 Columbia Rd., Washington, D. C.

WHITE, Edward F. (1891), Cons. Engr., Sulphur Plants, Pres., Rutland Mfg. Co., Rutland, Vt.

WICK, Henry (Associate, 1903), 416 Wick Ave., Youngstown, O.

NEW MEMBERS

AKERLIND, G. A. (1909), Cons. Engr., 664 Monadnock Bldg., Chicago, Ill.

BARKER, Perry (Junior, 1909), Chemical Engr., A. D. Little, Inc., 93 Broad St., Boston, Mass.

BORDE, George U. (1909), Cons. Engr., 914 Hibernia Bldg., New Orleans, La.

BOYER, Frederic Quintard (Junior, 1909), 216 Orchard St., New Haven, Conn.

BROWN, Stephen P. (1909), Engrs.' Club, 32 W. 40th St., New York, N. Y.

BULKELEY, Claude A. (1909), Ch. Engr., Board of Education, St. Louis, Mo.

CHAPMAN, Frank T. (1909), Prop., Chapman Mfg. Co., Marbridge Bldg., New York, N. Y., and Montclair, N. J.

CHESS, Harvey B., Jr. (Junior, 1909), 808 Aiken Ave., Pittsburg, Pa.

CROGHAN, John T. (Associate, 1909), Ch. Engr., Concord Elec. Co., and 15 Capitol St., Concord, N. H.

DAMON, Walter Henry (1909), Supt. of Generating, United Elec. Light Co., 87 Greenwood St., Springfield, Mass.

DILLON, Edward L. (1909), Rep., Fairbanks, Morse Co., and 1330a Clara Ave., St. Louis, Mo.

ERNST, Alfred F. (Junior, 1909), Brighton Mills, and *for mail*, 434 Lafayette Ave., Passaic, N. J.

ESSELSTYN, Horace H. (1909), Engr., Westinghouse, Church, Kerr & Co., 10 Bridge St., New York, N. Y., and *for mail*, 296 Vinewood Ave., Detroit, Mich.

FUCHS, Herman (1909), Mgr., Mexican Dept., Fairbanks, Morse Co., and 3910 Cleveland Ave., St. Louis, Mo.

GILMORE, George F. (1909), Local Engr., Am. Thread Co., and 109 Barre St., Fall River, Mass.

GOETZ, Fred. W. (Associate, 1909), Secy., Goetz & Flodin Mfg. Co., Clybourn Ave. and Willow St., and 5960 Kenmore Ave., Chicago, Ill.

HAZELTON, Robert T. (Junior, 1909), Designer, Bridgeford Mch. Tool Co., 225 Mill St., Rochester, N. Y.

HELLER, H. Howard (1909), Eastern Sales Mgr., Hill Clutch Co., 50 Church St., New York, N. Y.

HENES, Harry Wm. (Junior, 1909), 307 E. Green St., Champaign, Ill.

HOUGHTON, Clyde Arthur (Junior, 1909), P. H. B. & N. C. Ry. Co., Eidenau, Pa.

HUNTER, John (1909), Ch. Engr., Union Elec. Light & Power Co., and 4462 Laclede Ave., St. Louis, Mo.

JONES, William R. (1909), Engr. of Constr., Univ. of Pa., and *for mail*, 550 S. 48th St., Philadelphia, Pa.

KENYON, Wm. Houston (1909), Member of Firm, Kenyon & Kenyon, 49 Wall St., New York, N. Y.

KERR, William C. (1909), Mech. Engr., Philadelphia Rapid Transit Co., 9th and Dauphin Sts., and 3322 N. 17th St., Philadelphia, Pa.

KOCH, George B. (1909), Foreman, Loco. Testing Plant, Pa. R. R., and *for mail*, 809 Chestnut St., Altoona, Pa.

LORD, Chas. Edward (1909), Elec. Pat. Atty., Allis-Chalmers Co., Milwaukee, Wis.

LUNDGAARD, Ivar (Junior, 1909), Industrial Engr., Rochester Ry. & Light Co., and *for mail*, 34 Clinton Ave., Rochester, N. Y.

McCARTHY, Harry (1909), Ch. Draftsman, Natl. Tube Co., and 600 E. Prospect St., Kewanee, Ill.

McMILLAN, Chas. M. (Junior, 1909), Cons. Engr., King Edward Hotel, 145 W. 47th St., New York, N. Y.

MONAGHAN, James F. (1909), Mech. Engr., Waltham Bleachery & Dye Wks., and 2 Oak St., Waltham, Mass.

MORETON, George Wm. (1909), Genl. Supt., Betts Mch. Co., and 1323 Gilpin Ave., Wilmington, Del.

MOYER, Allen V. (Junior, 1909), Asst. Secy., Lyons Boiler Wks., P. O. Box 221, De Pere, Wis.

NEWLIN Alexander Z. (1909), Mech. Engr., Natl. Tube Co., and *for mail*, 600 S. Tremont St., Kewanee, Ill.

NORRIS, William H., Jr., (Junior, 1909), Engr., W. R. Grace & Co., and *for mail*, 1 Hanover Sq., New York, N. Y.

OHMES, Arthur K. (1909), Member of Firm, Nygren, Tenney & Ohmes, 87 Nassau St., New York, N. Y.

PALMER, George W., Jr. (1909), Elec. Engr., Old Colony St. Ry. Co., Boston & Northern St. Ry. Co. and Hyde Park Elec. Light Co., 84 State St., Boston, Mass.

PEDDLE, John Bailey (1909), Prof. Mch. Design, Rose Poly. Inst., and *for mail*, 2117 N. 10th St., Terre Haute, Ind.

RICHARDS, Willard F. (1909), Mech. Supt., Gould Coupler Co., Depew, N. Y.

ROELKER, Carl J. (1909), Cons. Engr., Roelker & Lee, State Bank Bldg., Richmond, Va.

ROHLIG, Georg G. (1909), Genl. Supt., Botany Worsted Mills, and 145 Dayton Ave., Passaic, N. J.

SHERWOOD, Mather Wm. (1909), Genl. Inspr., Board of Aqueduct Commrs., and *for mail*, 1090 St. Nicholas Ave., New York, N. Y.

SMITH, Harry J. (1909), Ch. Engr., Hill Clutch Co., Cleveland, O.

STROTHMAN, Louis E. (1909), Asst. Mgr., Pumping Eng. and Hyd. Turbine Dept., Allis-Chalmers Co., Milwaukee, Wis.

STROUSE, Sidney B. (Junior, 1909), Engr., Pa. Engrg. Co., and *for mail*, 1326 N. Marshall St., Philadelphia, Pa.

STURGIS, Wm. Bayard (Junior, 1909), Asst. Engr., Dover White Marble Co., Wingdale, Duchess Co., N. Y.

TYDEMAN, William A. (Junior, 1909), Secy., Macan Jr. Co., and 108 S. 2d St., Easton, Pa.

VANDERGRIFT, James W. (1909), Supt. National Transit Co., Southern Pipe Line Co., Crescent Pipe Line Co., and Eureka Pipe Line Co., and 665 W. Chestnut St., Lancaster, Pa.

WERST, Chas. Wm. (1909), Genl. Foreman, Erecting Dept., Baldwin Loco. Wks., Philadelphia, and *for mail*, 4603 Greene St., Germantown, Philadelphia, Pa.

PROMOTIONS

MARSHALL, Wm. Crosby (1901; 1909), Asst. Prof., Descriptive Geom. and Drawing, 114 Winchester Hall, S. S. S., Yale Univ., and *for mail*, 201 Edwards St., New Haven, Conn.

SCHREUDER, Andrew M. (1898; 1909), Supt., Phila. Textile Mchy. Co., Hancock and Somerset Sts., Philadelphia, and *for mail*, 6201 Germantown Ave., Philadelphia, Pa.

WALKER, Frederick Wiley (1898; 1909), V. P. and Ch. Engr., Comstock, Haigh, Walker Co., 1018–20 Ford Bldg., Detroit, Mich., and *for mail*, Cedarburg, Ozankee Co., Wis.

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METCALF, William. SWINSCOE, Charles. WILLCOX, Chas Henry.

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CHAPMAN, W. B. (Affiliate, 1908), Pres., Chapman Engrg. Co., 50 Church St., New York, N. Y.

COLLETT, S. D. See mem. Am. Soc. M. E.

HOPKINS, George Jay (Affiliate, 1909), Natl. Ry. Devices Co., 490 Old Colony Bldg., Chicago, Ill.

ROTH, Charles (Affiliate, 1909), Mech. Engr., Liquid Carbonic Co., Chicago, and *for mail,* 220 Marion St., Oak Park, Ill.

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DAVIS, Harvey N. (Affiliate, 1909), Instr., Harvard Univ., 509 Craigie Hall, Cambridge, Mass.

HAGUE, Charles A. See mem. Am. Soc. M. E.

HOBART, Douglas R. (Affiliate, 1909), Tech. Editor, Collier's, and *for mail,* 65 W. 93d St., New York, N. Y.

JENKINS, Alexander Lewis. See mem. Am. Soc. M. E.

MOSES, Frank D. (Affiliate, 1909), Pres., Gas Engrg. Co., Trenton, N. J.

MOSES, Percival R. (Affiliate, 1909), Cons. Engr., 45 W. 34th St., New York, N. Y.

MYERS, Cornelius T. See mem. Am. Soc. M. E.

SPURLING, O. C. See mem. Am. Soc. M. E.

STEVENS, Henry R. (Affiliate, 1909), Cons. Engr., 610 Bailey Bldg., Seattle, Wash.

STOUT, Oscar M. (Affiliate, 1909), Engr., 972 Dean St., Brooklyn, N. Y.

STRITMATTER, Albert (Affiliate, 1909), Secy. & Treas., Gas Engine Pub. Co., and 224 E. 7th St., Cincinnati, O.

TYLEE, Don O. (Affiliate, 1909), 1233 Washtenaw, Ann Arbor, Mich.

WINSHIP, W. E. See mem. Am. Soc. M. E.

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CHANGES OF ADDRESS

CARNAHAN, O. A. (Student, 1909), 212 E. Clark St., Champaign, Ill.
COLEMAN, Wm. F. (Student, 1909), Rm. 337, Association Hall, Champaign, Ill.
HEILMAN, H. C. (Student, 1909), 1005 S. 4th St., Champaign, Ill.
JAPPE, Kurt W. (Student, 1909), Main Belting Co., 1241 Carpenter St., Philadelphia, Pa.
LUND, J. C. (Student, 1909), 305 S. Wright St., Champaign, Ill.
McGINNIS, H. D. (Student, 1909), H. B. Smith Co., Westfield, Mass.
WOLF, J. E. (Student, 1909), address unknown.

NEW MEMBERS

ARMOUR INSTITUTE OF TECHNOLOGY

BAUGHMAN, I. N. (Student, 1909), 3166 Lake Park Ave., Chicago, Ill.
BOLTE, E. E. (Student, 1909), 3757 Ellis Ave., Chicago, Ill.
BYERS, A. A. (Student, 1909), 7321 Union Ave., Chicago, Ill.
CARLSON, H. W. (Student, 1909), 2138 Walnut St., Chicago, Ill.
CROCKER, A. H., Jr. (Student, 1909), 650 Barry Ave., Chicago, Ill.
GENTRY, T. E. (Student, 1909), Hotel Metropole, 23d & Mich. Ave., Chicago, Ill.
GILBERT, J. B. (Student, 1909), 3325 Armour Avenue, Chicago, Ill.
GRENOBLE, H. S. (Student, 1909), 4312 Champlain Ave., Chicago, Ill.
GRIFFITH, F. H. (Student, 1909), 3343 Calumet Ave., Chicago, Ill.
HENWOOD, P. B. (Student, 1909), 300 E. 33d St., Chicago, Ill.
LOHSE, A. W. (Student, 1909), 3346 Dearborn St., Chicago, Ill.
McCAGUE, A. (Student, 1909), 140 No. Franklin Ave., Austin, Ill.
PARSONS, H. N. (Student, 1909), 3334 Armour Ave., Chicago, Ill.
THOMAS, W. E. (Student, 1909), 6500 Ellis Ave., Chicago, Ill.
WERNICK, F. E. (Student, 1909), 3316 Dearborn St., Chicago, Ill.
YOUNG, D. A. (Student, 1909), 3332 Armour Ave., Chicago, Ill.

BROOKLYN POLYTECHNIC INSTITUTE

SMALL, G. S., 3d. (Student, 1909), 61 Pierrepont St., Brooklyn, N. Y.

CORNELL UNIVERSITY

BATT, I. A. (Student, 1909), 115 College Ave., Ithaca, N. Y.
BOWER, F. A. (Student, 1909), 58 Thurston Ave., Ithaca, N. Y.
BROWN, C. S. (Student, 1909), 1 Central Ave., Ithaca, N. Y.

CANADY, M. S. (Student, 1909), 518 Stewart Ave., Ithaca, N. Y.
COMINS, H. N. (Student, 1909), 438 Cascad Bldg., Ithaca, N. Y.
CROSSMAN, D. M. (Student, 1909), 105 De Witt Pl., Ithaca, N. Y.
FAIRBANKS, F. L. (Student, 1909), 422 E. State St., Ithaca, N. Y.
GOLDBERG, M. S. (Student, 1909), 102 Highland Pl., Ithaca, N. Y.
GRAY, F. R. (Student, 1909), 113 De Witt Pl., Ithaca, N. Y.
HARDING, H. G. (Student, 1909), 704 E. Buffalo St., Ithaca, N. Y.
LINDSAY, H. D. (Student, 1909), 415 Stewart Ave., Ithaca, N. Y.
NIXDORFF, S. P. (Student, 1909), 221 Eddy St., Ithaca, N. Y.
PEACH, P. L. (Student, 1909), 306 Eddy St., Ithaca, N. Y.
REINICKER, N. G. (Student, 1909), 203 Williams St., Ithaca, N. Y.
REYNOLDS, H. B. (Student, 1909), 203 Williams St., Ithaca, N. Y.
SERRELL, J. J. (Student, 1909), 102 West Ave., Ithaca, N. Y.
SKINNER, H. A. (Student, 1909), Sheldon Court, Ithaca, N. Y.
TURNER, E. T. (Student, 1909), 404 Stewart Ave., Ithaca, N. Y.
UNCKLES, H. W. (Student, 1909), 226 Eddy St., Ithaca, N. Y.
WALL, R. E. (Student, 1909), 110 Osmun Pl., Ithaca, N. Y.
WESLEY, C. F. (Student, 1909), 203 College Ave., Ithaca, N. Y.
WING, S. R. (Student, 1909), 208 Dryden Rd., Ithaca, N. Y.
WOOD, A. P. (Student, 1909), 130 Dryden Rd., Ithaca, N. Y.
WOOD, S. V. (Student, 1909), 110 Osmun Pl., Ithaca, N. Y.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PAGE, Atwood C. (Student, 1909), 137 Newbury St., Boston, Mass.

UNIVERSITY OF ILLINOIS

KEOWN, B. L. (Student, 1909), 511 E. White St., Champaign, Ill.
MOSCHEL, H. (Student, 1909), 405 E. Green St., Champaign, Ill.

UNIVERSITY OF KANSAS

BRIGHAM, C. M. (Student, 1909), 23 E. Lee St., Lawrence, Mass.
HILFORD, W. H. (Student, 1909), 1025 Kentucky St., Lawrence, Kansas.
JOHNSON, C. E. (Student, 1909), 736 Maine St., Lawrence, Kansas.
PLANK, Wm. Jay (Student, 1909), 814 Alabama St., Lawrence, Kansas.

COMING MEETINGS

January and February

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the Editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

ALBERTA ASSOCIATION OF ARCHITECTS
: January, annual meeting, Edmonton. Secy., H. M. Whiddington, Strathcona.

AMERICAN MATHEMATICAL SOCIETY
: February 26, New York and San Francisco sections. Secy., F. N. Cole, 501 W. 116th St., New York.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS
: January 18–20, annual meeting, 29 W. 39th St., New York. Secy., W. M. Mackay, Box 1818.

AMERICAN SOCIETY OF HUNGARIAN ENGINEERS AND ARCHITECTS
: January 8, 29 W. 39th St., New York. Paper: Measurement of Feeble High Frequency Currents, Aurel Kozmutza. Secy., Zoltán de Németh.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
: January 11, February 8, 29 W. 39th St., New York. January 15, St. Louis. January 21, Boston. May 31–June 3, Spring Meeting, Atlantic City, N. J. July 26–29, joint meeting with Institution of Mechanical Engineers, England. Secy., Calvin W. Rice, 29 W. 39th St.

AMERICAN SOCIETY OF SWEDISH ENGINEERS
: January 8, annual meeting, 271 Hicks St., Brooklyn, N. Y. Secy., E. Hammerstrom.

ASSOCIATION OF ONTARIO LAND SURVEYORS
: February 22–24, annual meeting. Secy., Killaly Gamble, 703 Temple Bldg., Toronto.

BOSTON SOCIETY OF ARCHITECTS
: January 4, annual meeting. Secy., E. J. Lewis, Jr., 9 Park St.

BOSTON SOCIETY OF CIVIL ENGINEERS
: January 26, annual meeting, Chipman Hall, Tremont Temple. Secy., S. E. Tinkham, 60 City Hall.

CANADIAN SOCIETY OF CIVIL ENGINEERS
: Quebec Branch, January 21, annual meeting, Montreal. Secy., C. H. McLeod, 413 Dorchester St., W.

CIVIL ENGINEERS SOCIETY OF ST. PAUL
: January 10, annual meeting. Old State Capitol Bldg., 8 p.m. Secy., D. F. Jurgensen, 116 Winter St.

ELECTRIC CONTRACTORS' ASSOCIATION OF NEW YORK STATE
January 18, Utica, N. Y. Secy., Geo. W. Russell, 500 Fifth Ave., New York.

ENGINEERS CLUB OF PHILADELPHIA
February 5, annual meeting, 1317 Spruce St Secy., W. P. Taylor.

ENGINEERS SOCIETY OF PENNSYLVANIA
January 4, annual meeting, Harrisburg. Secy., E. R. Dasher, Gilbert Bldg.

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA
January 18, annual meeting. Secy., E. K. Hiles, 803 Fulton Bldg., Pittsburg.

FRANKLIN INSTITUTE
January 28, February 11, Witherspoon Hall, Philadelphia, Pa. Lectures: Road Administration and Maintenance, L. W. Page; Recent Methods for the Production of Light, R. H. Bradbury.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS
January, annual meeting, Cairo. Secy., F. E. R. Tratman, 1636 Monadnock Blk., Chicago.

ILLUMINATING ENGINEERING SOCIETY
January 11, Royal Society of Arts, John St., Adelphi, London. Paper: Glare, its Causes and Effects, J. H. Parsons. Secy., L. Gaster, 32 Victoria St.

INDIANA ENGINEERING SOCIETY
January 14–16, annual convention, Indianapolis. Secy., Chas. Brossmann, Union Trust Bldg.

IOWA ENGINEERING SOCIETY
Fecruary 16–17, Cedar Rapids, Ia. Secy., A. H. Ford, Iowa City.

LOUISIANA ENGINEERING SOCIETY
January 8, Hibernia Bldg., New Orleans, La. Secy., L. C. Datz, 321-322 Hibernia Bldg.

MICHIGAN AUTOMOBILE ASSOCIATION
January 25–26, Detroit. Pres., E. A. Skae, Hammond Bldg.

MICHIGAN ENGINEERING SOCIETY
January 12–14, annual meeting, Lansing. Secy., Alba L. Holmes, 574 Wealthy Ave., Grand Rapids.

MONTANA SOCIETY OF ENGINEERS
January 6–8, annual meeting, Butte. Secy., Clinton H. Moore.

NATIONAL ASSOCIATION OF AUTOMOBILE MANUFACTURERS
January 12, annual meeting, Madison Square Garden, New York. Secy., Benjamin Briscoe, 7 E. 42d St.

NATIONAL ASSOCIATION OF CEMENT USERS
February 21–25, Chicago. Secy., R. L. Humphrey, Harrison Bldg., Philadelphia.

NATIONAL CIVIC FEDERATION CONFERENCE
January 5–7, Washington, D. C. Secy., D. L. Cease, 281 Fourth Ave., New York.

NEBRASKA CEMENT USERS ASSOCIATION
Februrary 1–4, Lincoln. Secy., Peter Palmer, Oakland.

NEW ENGLAND GAS ASSOCIATION
February 16, 17, annual meeting, Boston. Secy., N. W. Gifford, East Boston.

NEW ENGLAND WATER WORKS ASSOCIATION
January 12, annual meeting. Secy., Willard Kent, 715 Tremont Temple, Boston, Mass.

NORTHWESTERN ELECTRIC ASSOCIATION
January, Milwaukee, Wis. Secy., R. N. Kimball, Kenosha, Wis.

PACIFIC COAST ELECTRIC AUTOMOBILE ASSOCIATION
February, Oakland, Cal. Secy., J. T. Halloran, 604 Mission St., San Francisco.

RICHMOND RAILROAD CLUB
January 11. Lectures: Block Signals, Chas. Stephens; Terminal Freight Handling, G. H. Condict. Secy., F. O. Robinson.

SOUTH DAKOTA INDEPENDENT TELEPHONE ASSOCIATION
January 11–13, Huron. Secy., E. R. Buck, Hudson.

SOUTHERN GAS ASSOCIATION
February 16, Chattanooga, Tenn. Secy., James Ferrier, Rome, Ga.

STEVENS ENGINEERING SOCIETY
January 4, 11, 18, 4.10 p.m., Stevens Institute, Castle Point, Hoboken, N. J. Papers: Engineering Efficiency, H. G. Stott, Mem.Am.Soc.M.E.; Warfare of the Future, Hudson Maxim; Features of Electrical Development, T. C Martin. Secy., R. H. Upson.

WESTERN SOCIETY OF ENGINEERS
January 12, annual meeting, Chicago. Secy., J. H. Warder, 1735 Monadnock Blk.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
January			
1	Amer. Soc. Hungarian Engrs. and Archts.	Z. deNémeth	8.30
5	Wireless Institute	S. L. Williams	7.30
6	Blue Room Engineering Society	W. D. Sprague	8.00
11	The American Society Mech. Engrs	Calvin W. Rice	8.15
12	American Society Engrg. Contractors	D. J. Haner	7.30
13	Illuminating Engineering Society	P. S. Millar	8.00
14	American Institute Electrical Engineers	R. W. Pope	8.00
18–20	Heating and Ventilating Engineers	W. M. Mackay	All day
18	New York Telephone Society	T. H. Lawrence	8.00
21	New York Railroad Club	H. D. Vought	8.15
26	Municipal Engineers of New York	C. D. Pollock	8.15
February			
2	Wireless Institute	S. L. Williams	7.30
3	Blue Room Engineering Society	W. D. Sprague	8.00
5	Amer. Soc. Hungarian Engrs. and Archts.	Z. de Németh	8.30
8	The American Society Mech. Engrs	Calvin W. Rice	8.15
10	Illuminating Engineering Society	P. S. Millar	8.00
11	American Institute Electrical Engineers	R. W. Pope	8.00
15	New York Telephone Society	T. H. Lawrence	8.00
18	New York Railroad Club	H. D. Vought	8.15
23	Municipal Engineers of New York	C. D. Pollock	8.15

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Terms expire at Annual Meeting of 1910

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Frederick W. Taylor .... Philadelphia, Pa.
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Henry G. Stott .... New York

Terms expire at Annual Meeting of 1910

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I. E. Moultrop .... Boston, Mass.
W. J. Sando .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft .... Philadelphia, Pa.
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Terms expire at Annual Meeting of 1912

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William H. Wiley .... New York

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Chas. B. Dudley (4), *Deceased*.

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SPECIAL COMMITTEES

1909

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
G. T. Voorhees
A. P. Trautwein
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
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On International Standard for Pipe Threads

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Chas. Wallace Hunt (1) | F. R. Hutton (2)
Fred J. Miller (3)

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J. W. Lieb, Jr., Chairman of the Library Committee of The Am. Soc. M. E.

On National Fire Protection Association

John R. Freeman | Ira H. Woolson

On Joint Committee on Engineering Education

Alex. C. Humphreys | F. W. Taylor

On Government Advisory Board on Fuels and Structural Materials

Geo. H. Barrus | P. W. Gates
W. F. M. Goss

On Advisory Board National Conservation Commission

Geo. F. Swain | John R. Freeman
Chas. T. Main

On Council of American Association for the Advancement of Science

Alex. C. Humphreys | Fred J. Miller

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

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1909

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J. R. Bibbins

SECRETARY
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F. R. Hutton
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	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	....	C. F. Hirshfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	C. F. Gebhardt	N. J. Boughton	M. C. Shedd
Leland Stanford, Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	P. H. Van Etten	H. L. Hess
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. A. Kirk	J. R. Jackson
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	H. S. Coleman	John Garver
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	W. F. Colman	S. G. Wood
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York	November 9	....	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Fredk. A. Dewey	A. P. Truette
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	H. B. Cook	P. G. Haines
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	....	....
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. E. Dudley	E. C. Phillips
Univ. of Nebraska, Lincoln, Neb.	December 7	....	....	....

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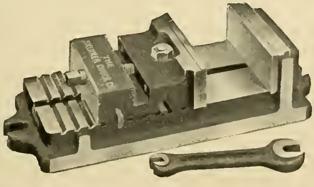
THE NATIONAL MACHINERY CO
TIFFIN, OHIO, U.S.A.



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SECTION 2

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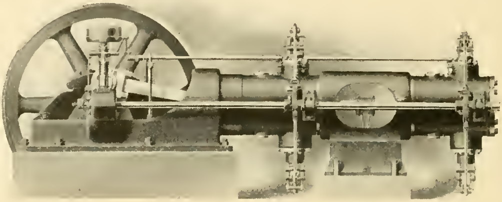

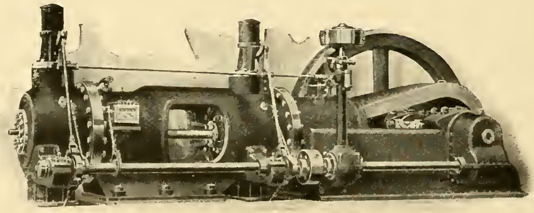

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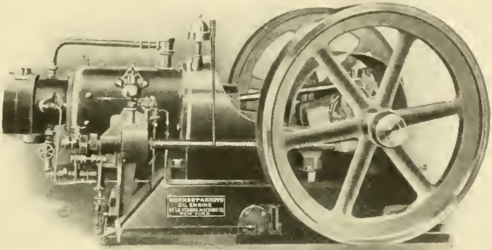

HORIZONTAL TYPE "HA" 10 to 250 H.P.

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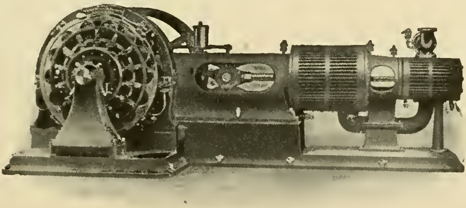

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Write for Bulletins-Collection H.

RIDGWAY DYNAMO AND ENGINE CO.

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ELECTRIC CONTROLLER & MFG. CO.
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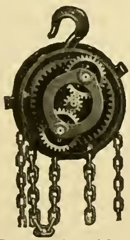
in the Triplex Block



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1194	Performance of Belt Conveyors, Haddock	.10
1195	Discussion on 1190, 1191, 1192, 1193, 1194	.30

Members' rates are half the list price.

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29 West 39th Street, New York

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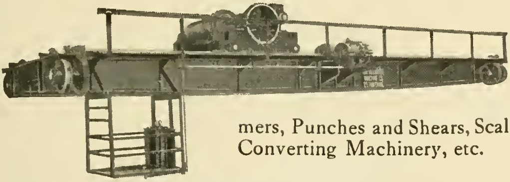

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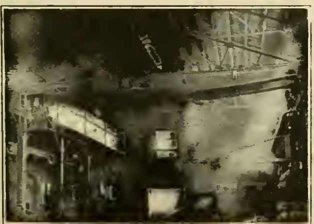

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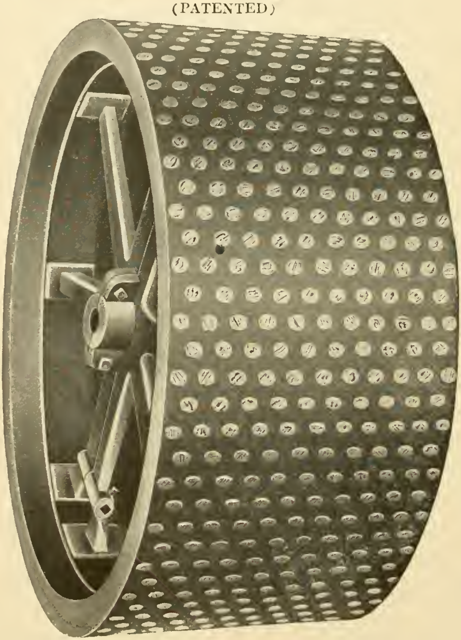

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ALPHABETICAL LIST OF ADVERTISERS

INDEX TO JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

January-December, 1909

If it is desired to remove the index for the purpose of binding with the 1909 Journals, raise the staples upright, when the section will slip off easily. Then flatten the staples again.

INDEX TO JOURNAL, JANUARY-DECEMBER, 1909

NOTE: Items appearing in The Journal as Society Affairs, have the month and page number given. Where the list of discussors of a paper is given, the list appears under the straight title of the paper. Papers published in The Journal for 1908, discussion of which was published in 1909, are indicated by the month followed by "1908." All papers, reports, etc., of the Gas Power Section appear under the heading Gas Power Section. All items concerning colleges and not referring to Student Branches are indexed under Colleges. Items regarding Student Branches are indexed under Sections. Miscellaneous items are indexed under Miscellaneous.

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THE

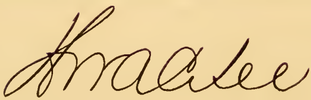
JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING THE PROCEEDINGS

FEBRUARY 1910

MEETINGS OF THE SOCIETY: NEW YORK, FEBRUARY 8; BOSTON, FEBRUARY 16; SPRING MEETING, ATLANTIC CITY, MAY 31 TO JUNE 3. MEETING IN BIRMINGHAM, ENGLAND, JULY 26 TO 29.



PRESIDENT 1888

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

FEBRUARY 1910 VOL. 32 No. 2

THE JOURNAL
OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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Contents continued on next page

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CONTENTS—Continued

The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 FEBRUARY 1910 NUMBER 2

THE New York monthly meeting for February will be devoted to the dedication of a bronze memorial tablet to Dr. Robert H. Thurston, the first president of The American Society of Mechanical Engineers. All associates and former students of Dr. Thurston are earnestly invited to attend these exercises to show their esteem for him as a friend and in recognition of his brilliant career as an engineer and educator.

Addresses will be given upon Dr. Thurston as a man, and his life work, by speakers of wide reputation who knew him intimately. These addresses will touch upon his experience as an engineer of the navy during the Civil War; his work as an educator at Stevens Institute of Technology and at Cornell University; his achievements as engineer and investigator; as an author; and his long relationship with The American Society of Mechanical Engineers.

Among those who will participate are Prof. John E. Sweet, closely associated with Dr. Thurston in the organization of the Society; Col. E. A. Stevens, the prominent representative of the Stevens family, founders of Stevens Institute; President J. G. Schurman of Cornell University; and Mr. William Kent, consulting engineer. Dr. Alex. C. Humphreys, president of Stevens Instutite,will be the chairman.

The beautiful memorial which is to be unveiled is the work of Herman H. McNeil, a former student and personal friend of Dr. Thurston. It is a replica of the memorial tablet presented to Sibley College, Cornell University, by alumni and students of the university. The tablet was placed in the rooms of the Society through the gener-

osity of members and their devotion of Dr. Thurston. Contributions were received by a committee consisting of John Fritz, S. W. Baldwin, Prof. R. C. Carpenter, W. C. Kerr, E. A. Uehling, Wm. Hewitt, and Gus C. Henning, The installation of the memorial and the arrangement for the dedicatory exercises were made by a committee consisting of Dr. Alex. C. Humphreys, *Chairman*, and Messrs. Chas. Wallace Hunt, Fred J. Miller, Prof. R. C. Carpenter and J. W. Lieb, Jr.

MEETING IN BOSTON, FEBRUARY 16

There will be a meeting of engineers in Boston on February 16 conducted by the American Institute of Electrical Engineers with the coöperation of The American Society of Mechanical Engineers and the Boston Society of Civil Engineers. The meeting will be held in the auditorium of the Boston City Club, 9 Beacon St. The subject of the meeting is Industrial Power, arranged for by the Industrial Power Committee of the American Institute of Electrical Engineers. Five papers will be presented, the authors being Prof. D. C. Jackson, Mem. Am. Soc. M. E., Charles T. Main, Mem. Am. Soc. M. E., Robt. S. Hale, Mem. Am. Soc. M. E., Geo. H. Stickney and W. B. Nye.

SPRING MEETING, ATLANTIC CITY, MAY 31–JUNE 3

The Spring Meeting of The American Society of Mechanical Engineers will be held this year as usual, in addition to the London Meeting which occurs in July. Atlantic City, N. J., has been selected by the Meetings Committee and approved by the Council as the place, and the meeting will be held from May 31–June 3 inclusive. The headquarters during the meeting will be at Hotel Marlborough-Blenheim.

NEW YORK MEETING, JANUARY 11

The New York monthly meeting for January drew out a profitable discussion on lubrication. The Society was fortunate in having for its guests Dr. C. F. Mabery. Professor of Chemistry at Case School, Cleveland and Dr. P. H. Conradson, chief chemist of the Galena-Signal Oil Company, Franklin, Pa. Dr. Mabery presented a paper, published in this number of The Journal, on Lubrication and Lubricants. The paper deals largely with laboratory tests in the performance of which Dr. Mabery has been signally successful and from which

he has deduced interesting results both withoils alone, and with oil and graphite and water and graphite.

Following Dr. Mabery's address, a paper by Prof. F. H. Sibley upon Efficiency Tests of Lubricating Oils, published in The Journal for November, was read by Dr. Charles E. Lucke. The discussion was lead by Dr. Conradson, who sought to show the extent to which laboratory practice might be expected to have a bearing on the performance of lubricants in actual practice and explained certain practical considerations that must be taken into account in the lubrication of different types of machinery. Others who contributed to the discussion were William M. Davis of Boston, Henry Souther of Hartford, Conn., F. R. Low. Dr. D. S. Jacobus, C. A. Hague, and George A. Orrok of New York.

MEETING OF THE COUNCIL

A meeting of the Council was held Tuesday, January 11, in the rooms of the Society. There were present, Charles Whiting Baker, Prof. R. C. Carpenter, George M. Bond, Charles Wallace Hunt, Dr. Alex. C. Humphreys, James Hartness, Prof. F. R. Hutton, I. E. Moultrop, Col. E. D. Meier, Jesse M. Smith, F. W. Taylor and H. G. Stott, and the Secretary. In the absence of the President, Dr. Humphreys was chosen Chairman.

The minutes of the meeting of December 10 were read and approved. The Secretary announced the following appointments by the President: Executive Committee, Dr. Alex. C. Humphreys, *Chairman*, Charles Whiting Baker, *Vice-Chairman*, H. L. Gantt, Prof. F. R. Hutton, F. M. Whyte; Standing Committees: Finance, A. M. Waitt, reappointed; House, H. R. Cobleigh; Library, Alfred Noble; Meetings, Willis E. Hall, reappointed; Membership, Theodore Stebbins; Publication, Geo. M. Basford; Research, James Christie, reappointed, and in place of Dr. Charles B. Dudley, deceased, Ralph D. Mershon.

Voted: To confirm the Executive Committee as named.

The resignations of Carl S. Dow, W. A. McFarland and R. Raymond were accepted.

Voted: To approve the action of the Meetings Committee in the appointment of the following sub-committees: on Sugar Machinery, H. deB. Parsons, Thos. F. Rowland and Dr. D. S. Jacobus; on Machine Shop Practice, L. R. Pomeroy, Prof. Walter Rautenstrauch and John Parker Illsley.

Voted: That the resignations of the Committee on Power House Piping be accepted.

Voted: To accept the invitation of the National Civic Federation to this Society, to be represented at the conference in Washington, January 17–19. In accordance with a vote of the Council, the Chairman appointed the following Honorary Vice-Presidents: Jesse M. Smith, Past-President, Chas. Kirchhoff, A. W. Burchard, E. G. Spilsbury, F. M. Whyte and Wm. H. Wiley.

Voted: To accept the resignations of the Committee on Land and Building Fund, in accordance with the request of the committee.

Voted: That the Executive Committee be requested to nominate to the Council a committee of three or more to take up this work; and that such recommendation be presented at the next meeting of the Council.

In accordance with previous discussion by the Council the following amendments were formally approved:

B 23 The Finance Committee shall consist of five Members or Associates The term of office of one member of the Committee shall expire at the end of each Annual Meeting. This committee shall, under the direction of the Council, have a supervision of the financial affairs of the Society, including the books of account. The Committee may cause the accounts of the Society to be audited and approved annually by a chartered or other competent public accountant. The committee shall hold monthly meetings for the audit of bills and such other business as shall come before it and shall deliver to the Secretary for presentation to the Council at the end of each fiscal year, a report of the financial condition of the Society for the past year, and also shall present therewith a detailed estimate for the probable income and expenditure of the Society for the following twelve months. It shall make recommendations to the Council as to investments, and, when called upon by the Council, advise upon financial questions. It shall have charge of the making of all contracts and other obligations to pay money in the Society's work and the ordering of all expenditures thereunder.

B 25 The Publication Committee shall consist of five Members or Associates. The term of office of one member shall expire at the end of each Annual Meeting. The Committee shall review all papers and discussions which have been presented at the meetings, and shall decide what papers or discussions, or parts of the same shall be printed in the Transactions of the Society. The Committee shall have the supervision of the monthly publication of the Society known as "The Journal." The Committee will be expected to publish all such data as will be of assistance to engineers or investigators in their work. At the end of each fiscal year the Committee shall deliver to the Secretary for presentation to the Council, a detailed report of its work.

On behalf of the Executive Committee, Charles Whiting Baker reported that the S. S. Celtic, sailing July 16, had been selected as the

vessel on which the main party attending the Joint Meeting in England would cross.

I. E. Moultrop, Chairman of the Committee on Meetings of the Society in Boston, reported regarding the joint meeting with the American Institute of Electrical Engineers and Boston Society of Civil Engineers, to be held January 21, and presented in the name of his committee an invitation to members of the Council to be present.

On motion the meeting adjourned to February 8.

JOINT MEETING WITH THE INSTITUTION OF MECHANICAL ENGINEERS, BIRMINGHAM, ENGLAND, JULY 26-29,1910

The Society has selected as the official steamer for the members and their families, *the mammoth twin-screw S. S. Celtic of the White Star Line,* which is scheduled to sail from *New York, Saturday, July 16, 1910, at 2 p.m. for Liverpool,* calling en route at Queenstown and Holyhead.

In order that we may retain our option of the *entire first-class accommodations of the Celtic,* it is necessary that all arrange to sail on this steamer.

THE OFFICIAL STEAMSHIP

The Celtic, 20,904 tons, ranks among the largest steamers in the world. Because of her exceptional steadiness and the general roominess of her staterooms and the public apartments, she is one of the most desirable of Atlantic steamers.

There is a large variety of passenger accommodations, among them several promenade and upper promenade suites, consisting of bedrooms and sitting rooms, with private bath and toilet rooms. A limited number of single staterooms, for the sole occupancy of one passenger, may be had; and there are numerous outside and inside cabins at various prices. The four promenade decks present unexcelled opportunities for rest in a steamer chair or exercise and games on deck.

The Celtic is fitted with Marconi wireless, submarine signaling apparatus and other modern safety devices.

SPECIAL RATES

From the regular tariff rates of the Celtic, the Committee has secured for our members a reduction of ten per cent, except when such a rebate would cause the price to fall below $97.50, the fixed minimum rate. For example, the rate for room 117 is $300 when occupied by two persons; but with the 10 per cent rebate the price will be $270 for two, or $135 each.

EARLY DECISION ESSENTIAL

As our option upon the Celtic's accommodations is necessarily limited because of the great pressure from the general public to leave America on this popular ship and date, all who decide to sail should communicate promptly with the *White Star Line, 9 Broadway, New York*, where all correspondence should be sent. The decision must be made before February 15.

HOTEL AND RAIL ARRANGEMENTS

The meetings will begin in Birmingham on Tuesday, July 26, and complete arrangements will be made for landing the entire party, Sunday, July 24, in Liverpool, and conveyance to and reservations in a hotel in that place. Monday will be spent in Liverpool; on Tuesday morning, the party will be conveyed by a special train to Birmingham and located in hotels in the latter city.

SIDE TRIPS

Side trips in England, on the Continent, or to any part of the world, can be arranged through the White Star Line, which will gladly reply to all inquiries. If members will immediately indicate their preferences in this matter, the White Star Line will act as a clearing house to bring together those who may have similar intentions.

THE RETURN TRIP

As the rush of return travel from Europe to America always taxes all available passenger accommodations between August 15 and September 25, members are strongly advised to secure round trip tickets now. For those who desire to return by any of the following lines, namely, White Star Line, American Line, White Star-Dominion, Atlantic Transport, Leyland and Red Star Line, the International Mercantile Marine Company (which controls them) is prepared now to make reservations *at regular rates*. The sailing dates of the various steamers will be furnished on application to the White Star Line. The bookings for European travel are the heaviest in history, and failure to reserve return passage immediately may result in serious inconvenience. Should members desire to return by other lines, the return tickets are interchangeable, but the necessity to reserve accommodations now is imperative in any case.

As the Society is the guest of the Institution of Mechanical Engineers, it will be impossible to include in the party gentlemen guests. The invitation which the Society accepted is extended only to the members and their immediate families.

On the last page will be found a list of members who have already signified their intention to attend.

Correspondence regarding the outgoing passage, reservations, side trips, etc., should properly be conducted direct with the White Star Line, 9 Broadway, New York. On the other hand the committee will be pleased to answer any communications.

ALEX. C. HUMPHREYS, *Chairman* CHARLES WHITING BAKER, *Vice Chairman* H. L. GANTT F. R. HUTTON F. M. WHYTE	Executive Committee

CALVIN W. RICE, *Secretary.*

ATTENDANCE AT THE JOINT MEETING

The following members, accompanied by 137 ladies, have signified their intention to attend:

The President

GEORGE WESTINGHOUSE

Past-Presidents

PROF. F. R. HUTTON, *Honorary Secretary* OBERLIN SMITH JESSE M. SMITH
AMBROSE SWASEY F. W. TAYLOR WORCESTER R. WARNER

Vice-Presidents

W. F. M. GOSS COL. E. E. MEIER F. M. WHYTE

Managers

H. L. GANTT JAMES HARTNESS

Treasurer WILLIAM H. WILEY

Chairman Membership Committee WILLIS E. HALL

Secretary CALVIN W. RICE

E. T. Adams
Edwin H. Ahara
John G. Aldrich
C. J. Angstrom
G. Ayres
Abram T. Baldwin
C. Kemble Baldwin
William J. Baldwin
S. G. Barnes
Edward P. Bates
Charles L. Bauer
Laurence V. Benet
Wm. P. Bettendorf
Sydney Bevin
C. H. Bierbaum
F. B. Bigelow
Charles W. H. Blood
J. H. Bloomberg
Robert W. Boenig
R. P. Bolton
Wm. T. Bonner

George A. Boyden
Geo. M. Brill
Morgan Brooks
John Calder
Henry W. Carter
David A. Chapman
A. G. Christie
A. W. Colwell
Jas. V. V. Colwell
Frederick N. Connet
Geo. M. Conway
Morris Llewellyn Cooke
J. C. Cromwell
F. Daugherty
Charles Ethan Davis
F. W. Dean
D. de Lancey
James B. Dillard
Henry B. Dirks
W. F. Dixon
William T. Donnelly
Walter C. Durfee
H. Emerson
Q. N. Evans
Thomas M. Eynon
John P. Faber
A. D. Finley
H. D. Fisher
F. A. Flather
B. P. Flint
E. H. Foster
William Fox
Harry C. Francis
Lawford H. Fry
R. W. Fuller
Francis E. Galloupe
E. A. Garratt
William Gleason
F. A. Goetze
Geo. E. Hallenbeck
Chester B. Hamilton, Jr.
J. A. Herrick
Henry Hess
C. P. Higgins
M. P. Higgins
E. L. Hill
Thos. Hill
Lewis G. Howlett
Leigh A. Hunt
Dugald C. Jackson
E. L. Jahncke
Herman G. Jakobsson
E. H. Jewett
William J. Keep
L. H. Kenney
J. G. Kingsbury
Charles Kirchhoff
Frank B. Klock
G. L. Kothny
H. M. Lane
Nisbet Latta
R. K. LeBlond
Wilfred Lewis
J. H. Libbey
Wm. Lodge
Charles Longstreth
F. R. Low
Robert T. Lozier
Walter MacGregor
H. B. MacFarland
J. Macfarland
Robert A. McKee
James W. McLaughlin
Charles T. Main
A. K. Mansfield
Thos. Marrin
W. C. Marshall
R. E. Mathot
A. V. Matlack
Geo. Mesta
E. W. Mix
W. O. Moody
Robert C. Monteagle
L. H. Morgan
R. L. Morgan
James W. Nelson
Charles Z. Newell
J. G. O'Neil
Geo. A. Orrok
Henry S. Otto
Wm. F. Parish, Jr.
F. A. Park
J. C. Parker
F. A. Parkhurst
Charles H. Parson
C. D. Pettis
H. Hobart Porter
Jos. G. Prosser
Thos. C. Pulman
L. S. Randolph
E. Howard Reed
Joseph Reid
Julian Richmond
Addison A. Righter
J. M. Robinson
J. W. Roe
W. F. Rogers
Axel Sahlin
E. K. Sancton
Thomas H. Savery
C. H. Schlachter
Geo. Schuhmann
Arthur C. Scott
Alonzo B. See
E. C. Sickles
C. C. Simpson
Alton L. Smith
A. Parker Smith
Gubert S. Smith
H. F. Smith
F. H. Stillman
C. W. Stone
E. B. Stone
K. J. Sunstrom
H. H. Suplee
Frank H. Taylor
J. T. Taylor
F. W. Teele
B. L. Thompson
F. Thuman
Edw. D. Thurston, Jr.
John T. Tiplady
F. E. Town
H. P. Townsend
G. R. Tuska
Willard C. Tyler
John W. Upp
T. A. Van Der Willigen
Edward Van Winkle
P. V. Vernon
F. L. O. Wadsworth
Charles Wald
Adolph O. Wallichs
William Watson
H. H. Westinghouse
William Wilke
F. O. Willhofft
C. N. Wills
Robert York

ENGINEERS' DINNER AT BOSTON

On Friday evening, January 21, upwards of 425 engineers, representative of the engineering profession as a whole, attended the dinner at the Hotel Somerset, Boston, given by The American Society of Mechanical Engineers, the Boston Society of Civil Engineers, and the Boston branch of the American Institute of Electrical Engineers to the presidents of these societies, George Westinghouse, George B. Francis and L. B. Stillwell; to John A. Benzel, president of the American Society of Civil Engineers and other distinguished guests. While the attendance was mainly from Boston and vicinity, there was a large representation from New York and a considerable number from other cities. This was the largest and most enthusiastic meeting that the Boston engineers have held and it emphasized in an unmistakable way the cordial relations existing between the different branches of the profession and the earnest desire for coöperation. There were present eight presidents of engineering societies or institutions, besides prominent members of many others, including architectural and scientific societies closely identified with the work of engineers. The following is the list of guests and others seated at the head table at the dinner:

C. B. Edwards, chief engineer, Fore River Ship and Engine Building Co.; Arthur Warren; Asa M. Mattice, manager of works, Walworth Mfg. Co., S; Boston, Mass.; Lieut-Com. O. G. Murrfin of the North Dakota; Prof. C. F. Allen, of the Massachusetts Institute of Technology; G. A. King, president, N. E. Water Works Association; Prof. D. C. Jackson, Massachusetts Institute of Technology; E. A. Engler, president, Worcester Polytechnic Institute; Desmond Fitzgerald, member, Metropolitan Water Committee; John A, Bensel, president, American Society of Civil Engineers; Elihu Thomson; Geo. B. Francis, president, Boston Society of Civil Engineers; Prof. Ira N. Hollis, Harvard University, Chairman Boston Local Com. Am.Soc.M.E.; George Westinghouse, President, Am.Soc.M.E.; Charles Francis Adams; L. B. Stillwell, President, American Institute Electrical Engineers; Prof. Geo. F. Swain, Harvard University; Jesse M. Smith, Past-President, Am.Soc.M.E.; W. D. Wright, president, N. E. Street Railway club; Calvin W. Rice, Secretary, Am.Soc.M.E.; R. Clepston Sturgis, president, Boston Society of Architects; Chas. T. Main, Boston, Mass.; I. E. Moultrop, mechanical engineer, Edison Elec. Ill. Co. of Boston.

Following the dinner, C. B. Edwards, chief engineer of The Fore River Shipbuilding Company, gave a talk, illustrated by lantern slides, on The Main and Auxiliary Machinery of the Blatteship North Dakota. This is the new "Dreadnaught" of the U. S. Navy, turnbine driven of 20,000 tons capacity. Photographs were thrown on the screen of the ship under trial, of the machinery after installation, and many detail drawings were shown of the arrangement of the boilers, machinery and piping.

Prof. Ira N. Hollis of Harvard University, chairman of the committee on meetings of the Society in Boston, acted as toast master and referred to an inquiry made when he came to Boston 17 years ago as to why he had removed "to that remote corner of the country where the engineering efforts were but feeble compared with those of the West." He said the criticism was true geographically but that Boston was in fact a great center of engineering, examples of which he instanced. He then introduced the next speaker, Mr. George B. Francis. president of the Boston Society of Civil Engineers. the oldest engineering society in America, which has for some time had under discussion the question of an engineering building and clubhouse.

This matter, said Mr. Francis. has been considered by a committee of the Boston Society of Civil Engineers, but the available funds are not enough to enable this Society to build on its own account. The committee, therefore, considered the possibility of coöperation with other local societies and with local members of the national engineering societies, making the building a headquarters for the city. Within a radius of 15 miles of Boston about 5000 men are engaged in engineering and architecture and the committee has suggested that such a body might well combine and organize a stock company to control a property which should be a home for local engineers and embrace a clubhouse with restaurant, smoking rooms, sleeping rooms and other features. He outlined a plan for carrying out this idea, including provision for revenue. If it becomes evident, he said, that there is a real demand for some of the wealth and standing of Boston sufficient money can be raised to carry out the project.

Mr. John A. Benzel, president of the American Society of Civil Engineers, warmly advocated the plan proposed by Mr. Francis, saying that an engineers' club could be maintained in a dignified form, keeping well within the spirit of the profession, which would not only agreeably fill the needs for companionship, but would widen the horizon of the different members of the profession.

The plan was also approved by R. Clepston Sturgis of the Boston

Society of Architects and L. B. Stillwell, president of the American Institute of Electrical Engineers, who took the occasion also to speak happily of the relations existing between mechanical and electrical engineers and of the need for coöperation; and in his remarks he further paid a tribute to Mr. Westinghouse saying that for 40 years, during which there has been so tremendous a development of industries, he has stood in the very forefront. It has not been a matter of financial results, merely but of a multitude of inventions promoting the comfort of society and protecting it against dangers resulting from new engineering developments.

At the close of the meeting, Prof. D. C. Jackson made a motion, seconded by I. E. Moultrop and C. E. Clark, to the effect that a joint committee be appointed to consider the matter of rasing funds and making plans for the erection of an engineering building and clubhouse in Boston.

Following the speech of Mr. Stillwell, Hon. Charles Francis Adams said a few words of appreciation of Mr. Westinghouse, his intimate friend, after which Mr. Westinghouse was introduced and given a very hearty welcome, the audience rising. An abstract of Mr. Westinghouse's remarks is given below.

The committee having charge of this successful event consisted of Prof. Ira N. Hollis, chairman; Prof. Edward F. Miller and J. H. Libbey for the Mechanical Engineers; H. F. Bryant and F. H. Fay for the Boston Society of Civil Engineers and N. J Neall and J. F. Vaughan for the Electrical Engineers.

ADDRESS BY GEORGE WESTINGHOUSE

It seems fitting and logical that we should encourage closer and more intimate relations among all engineering societies, in order that we may benefit from the power and influence which comes from combined efforts, and by working on broad, generous lines cause individual and professional prejudice to give way to that healthful condition of mind so necessary to correct conceptions and actions.

For many years the tendencies have been toward large and powerful railway and industrial combinations and their constant skilful development. The very magnitude of these, with the evil practices so frequently disclosed, has so aroused the public that there is a fixed determination to establish an exacting governmental control of practically all forms of corporation in order that competition may be encouraged and not stifled, but seemingly without due regard to

the real objects in view, viz., the securing of the best public service in all forms; the best foods and goods for our daily needs; the greatest possible comfort to the masses; and as great freedom as possible from those restrictions which hinder rather than promote honest endeavors.

Fortunately there are indications, of which this gathering is one of many, that the great leaders in our affairs (as witness the meetings of the Governors of numerous States now being held in Washington) are alive to the importance of *the regulation of legislation* and the creation of sentiments which will bring business men to their senses.

The engineering societies, by like joint action, have it in their power to do much to better conditions. Probably there is no better way for them to do so than to show, from their knowledge and experience, that *unregulated competition and rivalry in business* have established conditions which have made our costs greater and rendered ideal conditions in industrial engineering matters most difficult of realization.

To make this clear, I need only call attention to the effects of this unregulated competition in one great industry—the electrical—which has grown up in less than twenty-five years. No user of electrical apparatus can fail to appreciate the advantage if when some repair part was needed certain standards had been followed, but it is a lamentable fact that with the single exception of uniform bases for incandescent lamps, there are now practically no standards.

To illustrate the points I have tried to bring to your attention, I quote as follows from a letter on this subject:

> To illustrate the growth in the number of motor ratings required now as compared to the earlier days when sixty ratings sufficed, a summary is given of the motors manufactured by the company with which I am connected. *These figures refer to stationary motors only in sizes up to 200 h.p.* All of these motors are regularly manufactured and no special motors are included.
>
> For direct current, 55 frames are used giving 1600 ratings.
> For alternating current, 80 frames are used giving 1950 ratings.
> Or a total of 135 frames are used giving 3550 ratings.
>
> Practically anyone of these may be furnished in three types: (*a*) shaft horizontal, (*d*) shaft vertical, (*c*) with counter shaft bracket and bearings mounted on the frame. This makes a total of three times 3550, or something over 10,000 different motors available. In spite of this, there is a constant and increasing demand for special motors. In tbe past year approximately 10,000 estimates have been made on special motors under 200 h.p.. even though the greatest effort has been made to divert all inquiries to our regular lines of motors.

Many of these special estimates were necessary because the prospective customer wanted a motor having the same characteristics as a motor offered by some other manufacturer. Our standard motor may have differed in any one of the following characteristics: *a* Horse power or speed rating; *b* Dimensions of base; *c* Overall dimensions; *d* Height from base to center of shaft; *e* Weight; *f* Method of lubrication; *g* Size of shaft; *h* Performance guarantees.

This demand for special apparatus places a heavy burden on the manufacturer. The purchaser also suffers because of increased cost and long deliveries.

Consideration of the above and a general review of the situation leads to the conclusion that the benefits that will result from standardization will more than compensate for the work and expense required in making the necessary changes.

While these particulars relate only to a part of the motors made by one large company, it must not be forgotten that there are half a hundred others manufacturing equivalent lines of motors and that each maker has his own patterns and designs, so that it is safe to say there are fifty or more thousands of needless variations in motors which have added many millions of dollars to the investment already made in installations of electrical machinery.

I have long believed, and have urged upon my associates, for the fourteen years during which the two large electrical companies have had the joint use by a license agreement of several thousands of patents relating to their business, that by coöperation in the development of apparatus, by the use of the same designs, and by the exchange of engineering and manufacturing particulars, there would be evolved the very best of all kinds of electrical machinery and details, and that the products of the two companies could be made interchangeable, not only to the advantage of purchasers and users of electrical apparatus, but also to the advantage of the companies themselves. Other views have prevailed, however, and there has existed an unregulated competition which has made the electrical industry about the poorest of all in the matter of profits.

There are many here who know of the consequences of the adoption of different gages for railways, the final result being a change involving enormous expense to those railways having the disadvantage of having adopted a standard which differed from that of their more powerful neighbors. Unless there be some action in the near future, by those who have the gift of foresight, we shall soon have a like difficult condition to meet, due to the establishing of widely different systems for the electrification of our main railways. It seems certain that a system capable of universal use should be selected in the near future so that an electric locomotive or car of one railway could operate upon all other lines.

By a combined effort of all of the engineering societies, with the financial support of all manufacturers, who would be largely benefited and could well afford to pay in pro rata amounts the expense of a well-equipped and officered bureau of standardization, it seems to me such a bureau could be established, and could work a reform of incalculable value in our present practice, thus forestalling governmental activity in this direction.

The public needs no further incitement to the regulation of such matters by the Government. What is needed is such wise cooperation on the part of the large interests involved, and such fair consideration of the public rights, as may stay further governmental action and finally render it unnecessary.

GENERAL NOTES

LUNCHEON TO CHARLES KIRCHHOFF

Mr. Charles Kirchhoff, Mem.Am.Soc.M.E., recently retired as Editor of The Iron Age after a career of marked success in technical journalism for a period of thirty years, was tendered a luncheon at the Engineers' Club, New York, on Sunday afternoon, January 16, by a large number of engineers and personal friends. Mr. Kirchhoff will take a much deserved rest which will begin with a West Indian cruise; and while the immediate purpose of the gathering was to wish him a pleasurable voyage it was in reality an outward expression of the esteem in which he is held by his many friends and a recognition of his high accomplishments in his chosen field of professional work.

The luncheon was arranged by Philip T. Dodge, president of the Engineers' Club; T. C. Martin, Chairman Executive Committee, Museum of Safety and Sanitation; E. C. Brown, past-president, American Trade Press Association; Joseph Struthers, assistant secretary, American Institute of Mining Engineers: Theodore Dwight, secretary of committee. President Dodge presided at the luncheon.

Mr. Geo. W. Cope, the present editor of the Iron Age, spoke from an association of more than a quarter of a century with Mr. Kirchhoff, paying him a personal tribute and speaking of his quick perception of the bearing of new developments in commercial or technical progress and of his ability to inspire those around him with fresh zeal and interest in their work. He presented to Mr. Kirchhoff from his former associates a French bronze statute by Picault, entitled "La Source du Pactole." A figure typifiying the engineer holding dividers and hammer is pouring from an earthern jar a stream representative of the River of Pactolus, famed for the gold carried in its sands. The bronze was given as emblematical of the effective way in which its recipient, through his profession as engineer and editor, had contributed to the material benefit of those who had come under the influence of his publication in which is recorded the product of his life's work.

Among those who spoke was John Fritz of Bethlehem, Pa., Hon. Mem.Am.Soc.M.E., who, in spite of his advancing years came to

pay his respects. He expressed his high appreciation of the part contributed by Mr. Kirchhoff to the American iron trade. In the 1840's, pig iron production in the United States was less than 300,000 tons. In a recent year 27,000,000 tons was passed and now the country is producing at the rate of 32,000,000 tons a year. As editor of The Iron Age Mr. Kirchhoff had commented on developments in the industry year after year, described the best practice, analyzed the statistics of production, kept all in the industry informed as to the work of mechanical, metallurgical and electrical engineers in this country and abroad.

Many letters of appreciation were received from friends unable to attend. Among those read were letters from Andrew Carnegie, Hon.Mem.Am.Soc.M.E.; Ambrose Swasey, Past-President Am.Soc. M.E.; Chas. Whiting Baker, Vice-President Am.Soc.M.E.; Prof. Henry M. Howe; John Hays Hammond; John W. Lieb, Jr.; Mem. Am.Soc.M.E.; Robt. W. Hunt, Past-President Am.Soc.M.E. and Hon. William H. Wiley, Treasurer Am.Soc.M.E.

The following members of The American Society of Mechanical Engineers were in attendance: Ed. A. Uehling; Henry R. Towne; J. Waldo Smith; C. H. Zehnder; Colin C. Simpson; C. M. Wales; Henry D. Hibbard; F. A. Halsey; Wm. Schwanhausser; H. R. Cobleigh; J. M. Sherrerd; Albert W. Jacobi; W. L. Saunders; E. G. Spilsbury; Jesse M. Smith; W. H. Taylor; W. W. Macon; J. E. Denton; Walter Wood; John Fritz; Calvin W. Rice; H. F. J. Porter; S. S. Webber; Alex. C. Humphreys; Theo. Stebbins; W. H. Fletcher; Col. E. D. Meier; H. H. Suplee; Dr. Richard Moldenke.

WORCESTER ECONOMICS CLUB

At the fortieth annual meeting of the Worcester Economic Club, held January 13, at Worcester, Mass., Calvin W. Rice, Secretary, made an address on the topic of the evening, The Conservation of Natural Resources. He said in part:

Natural resources are essentially national resources, hence a subject pertaining to our national welfare should enlist the interest of every citizen.

Our natural resources are of two general classes, those capable of renewal, such as forests and those which may not be replenished, such as the minerals. Obviously the intelligent use of the latter is to make them go as far as they will, improving each year as we do in our methods.

We cannot proceed much further now without realizing that in the use of these resources we must recognize that each of us is a member of society, and that, after all, the fundamental problem is that of the individual versus

society. Where the political stops and the ethical begins, unnecessarily complicates the discussion, and I will not attempt it. Suffice to say, the individual may in the long run succeed only as the community succeeds; therefore, these two phases of the question may be considered together.

Mr. Rice was followed by Dr. George F. Swain, Mem.Am.Soc.M.E. professor of civil engineering at Harvard University, who argued that community rights must prevail over individual rights on conservation or the purpose of good government would be defeated. He gave statistics to prove the advantage of centralization of power companies over small companies.

Hon. Harvey N. Shepard represented the Appalachian Mountain Club and plead for conservation of the forests, with particular reference to the White Mountain conservation. He claimed that cutting the forests tended to fill the rivers with silt.

About 275 guests were in attendance at the meeting, which followed a dinner given by the Club.

FUNERAL OF STEPHEN W. BALDWIN

Honorary Vice-Presidents, appointed to represent the Society at the funeral of Stephen W. Baldwin, were George H. Barrus, Prof. I. N. Hollis, Chas. T. Main, I. E. Moultrop, Dr. C. J. H. Woodbury.

STUDENT BRANCHES

The first regular meeting of the recently organized Student Branch of the University of Wisconsin, held January 13, was addressed by Dean Goss of Purdue University. The officers of the Association are Prof. C. C. Thomas, Mem. Am. Soc. M. E., Honorary Chairman; R. N. Trane, Chairman; E. L. Kastler, Vice-Chairman; G. A. Glick, Secretary; J. S. Langwill, Assistant Secretary; R. A. Reudenbusch. Treasurer. A copy of the constitution has been received by the Society and placed on file.

The Stanford Mechanical Engineering Society of Stanford University holds bi-weekly meetings and during the past semester there have been papers on Grounding Devices by J. B. Bubb, The Hydroelectric on the Stanilaus River by E. A. Rogers, The Mechanics of the Aëroplane by Prof. W. F. Durand. Mem. Am. Soc. M. E., and the Electric Locomotive vs. the Steam Locomotive by Prof. S. B. Charters, among others. The officers of the society are Prof. W. F. Durand, Honorary Chairman; E. A. Rogers, President; A. F. Meston, Vice-President; H. C. Warren, Secretary-Treasurer.

OTHER SOCIETIES

AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers held its 57th annual meeting, commencing January 19, 1910, in the Society House in New York. The officers elected for the ensuing year were: President, John A. Bensel, New York; Vice-Presidents, J. T. Fanning, Minneapolis, Minn., Hunter McDonald, Nashville, Tenn.; Treasurer, Joseph M. Knap, New York; Directors, Wm. E. Belknap and Horace Loomis of New York, Geo. A. Kimball, Boston, Percival Roberts, Jr., Mem. Am.Soc.M.E., Philadelphia, Chas. F. Loweth, Chicago, Arthur D. Foote, Grass Valley, Cal.

In addition to the business sessions, the program included excursions to the new terminal station of the Pennsylvania Railroad of New York City and to the Ashokan Reservoir of the Board of Water Supply, New York. On Thursday evening, Walter McCulloh, consulting engineer of the State Water Supply Commission of New York, gave a lecture on the Conservation of the Water Resources of New York State.

AMERICAN INSTITUTE OF MINING ENGINEERS

The spring meeting of the American Institute of Mining Engineers will be held at Pittsburg, Pa., Tuesday March 1 to Saturday March 5 with headquarters at the Hotel Shanley. This will be largely a metallurgical meeting and members of The American Society of Mechanical Engineers will be welcomed to its sessions. Invitation cards may be had upon application to the Secretary of the Institute, at 29 West 39th Street, New York.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

At the meeting of the American Institute of Electrical Engineers on January 14, Prof. W. S. Franklin and Stanley S. Seyfert of Lehigh University presented a paper on The Space Economy of the Single-Phase Series Motor. The annual dinner of the Institute will be

held at the Hotel Astor on Thursday evening, February 24, with Prof. Elihu Thomson, who has been awarded the first Edison Medal, as the guest of honor.

At the December meeting of the Board of Directors of the Institute 74 Associate members were elected and 66 Students enrolled, while in January 88 Associates and 67 Students were received. The 1910 Year Book has just been issued.

INTERNATIONAL ASSOCIATION OF REFRIGERATION

At a meeting of the Council of the International Association of Refrigeration, held in Paris, December 3, 1909, Gardner T. Voorhees, Mem.Am.Soc.M.E., was elected a member of the Council, in place of Thos. S. McPheeter, deceased, to serve until the meeting of the Second International Congress at Vienna.

It was announced that the Vienna Congress would be held in the University Buildings from October 6-11, 1910, enabling the visitors to be present at the hunting and sporting exhibitions.

WESTERN SOCIETY OF ENGINEERS

The annual meeting and dinner of the Western Society of Engineers was held January 12, 1910 at the University of Chicago. Bernard E. Sunny, president of the Chicago Telephone Company, made the principal address of the evening, on The Engineering of Chicago. Mr. Sunny outlined the various broad plans for the development of public utilities and municipal improvements in Chicago proposed during the last two or three years, embracing sewers and a high-pressure water system for the central business district, the steam railway terminals of Chicago, plans of the Board of Local Improvements for replacing pavements in the business district, deep waterways, harbors and subways. The "Chicago Plan" prepared by the Commercial Club of Chicago, was also given extended consideration, and Mr. Sunny suggested that a board of engineers be created to compile the necessary engineering data relative to such a plan.

NEW ENGLAND WATER WORKS ASSOCIATION

One hundred and fifty members and guests attended the annual meeting of the New England Water Works Association held at the Hotel Brunswick, Boston, Mass., on January 12, 1910. Papers were presented on Governmental Policy in Relation to Water Power

by Marshall O. Leighton, discussed by Dugald C. Jackson, Mem. Am.Soc.M.E., Geo. F. Swain, Mem.Am.Soc.M.E., and Dwight Porter; and on the Maidstone Typhoid Epidemic, by Wm. T. Mason, discussed by Robert S. Weston. Geo. A. King was elected president and Willard Kent, Secretary.

NECROLOGY

HORACE SEE

Horace See, President of the Society in 1888, died in New York City on December 14, 1909.

He was born in Philadelphia, and after the usual classical and mathematical education of the private school entered the shops of I. P. Morris. Thence passing to Neafie & Levy, and the National Armor and Shipbuilding Co., at Camden, and Geo. W. Snyder of Pottsville, he entered on his best known life-work with William Cramp & Sons. He rose here to be designer and superintending engineer (in 1879), designing vessels and machinery of greatly improved construction and performance, introducing improved methods of work and standards in that great establishment, and giving to the United States a shipbuilding plant of capacity and quality to compare favorably with the products of the Clyde and Newcastle. It was under his leadership that the United States Navy contracts for the first vessels of what was then called the "New Navy of the United States" were taken, and the big ships of the American Line at that day bore his impress. It was at the zenith of this busy period, when he was confessedly the leader in his field, that the presidency of the Society was placed in his hands. He presided at the Nashville and Scranton meetings of 1888.

The following year it became apparent that avenues of professional advancement would not open further for him in Philadelphia, so that he came to New York with the honors thick upon him won from his busy years. He became at once consulting engineer for the Newport News Steamship and Dry Dock Company, and was the host of the Society on his visit to that plant at the Richmond meeting of 1890. He was superintending engineer for the Southern Pacific Company, and the Pacific Mail Steam Ship Co., superintendent for the Cromwell Steam Ship Co., and in his private practice as a marine engineer and naval architect he designed and prepared specifications for many yachts and commercial vessels. Some of his improvements in hull and machinery are in international use.

Mr. See was adjutant of the Twentieth Regiment of the National Guard of Pennsylvania during the riots of 1877, and later Captain of the First Pennsylvania Regiment. Besides various business and social connections, he was a member of the American Society of Naval Architects and Marine Engineers, of the Institute of Naval Architects of Great Britain, as well as of the Northeast Coast Institute of Engineers and Shipbuilders, and the American Geographical Society; associate member of the American Society of Naval Engineers and the United States Naval Institute; and fellow of the American Association for the Advancement of Science.

He contributed a paper on the method he introduced for producing true crank shafts for multiple-cylinder engines[1] his presidential address was a discussion of manual training and methods of instruction for technical work.

STEPHEN WARNER BALDWIN

In the death of Mr. Baldwin there has passed away another of the notable figures in the engineering history of the United States. He belonged to the era of practical training which brought forward so many gifted men in the nineteenth century, and to take part in the active developments following the Civil War.

He was born in Baldwinsville, N. Y., February 4, 1833, and received his early education in Homer in that state. He entered the Lawrence Machine Shops at Lawrence, Mass., as an apprentice under the late John C. Hoadley, dividing his three years between the machine shop, forge, boiler shop, and drawing-room. The admiration he felt for Mr. Hoadley lasted all through his life, and on the death of his old chief, both out of affection and out of sentiment, Mr. Baldwin was active in buying from the Hoadley estate a large amount of expert apparatus, which was made a gift to the Society.[2] Mr. Baldwin worked with Mr. Hoadley on his single-valve automatic engines and on his portable or farm engines. From this experience he always had a strong interest in the development of agricultural machinery for the West.

He later became manager of the Clipper Mowing Machine Works at Yonkers, N. Y., and was associated with the Johnson Iron Works at Spuyten Duyvil, N. Y., improving the machines of both of these companies with his own inventions. He soon became one of the promi-

[1] Transactions, Vol. 7, p. 521.

[2] Transactions Vol. 8. p. 349. Some of this apparatus remains in the possession of the Society as museum specimens. Other units have been sold and loaned where thay could be made useful.

nent mechanical engineers in the field of manufacture of steel and was president of the Spaulding & Jennings Co. But he will be principally remembered as the New York representative and agent for so many busy and successful years for the Pennsylvania Steel Company and the Maryland Steel Company. He remained with these companies until 1904 when he was retired, but was an honored adviser until his death.

Mr. Baldwin was intensely interested in the problems of education for the young engineer. When Milton P. Higgins proposed his scheme of half-time schools in which lads were to work at books for half the day and in the shop atmosphere for the other half, Mr. Baldwin's interest was not alone because the projector had been a fellow apprentice at Lawrence, but because he believed the idea to be sound. The Artisan School of Syracuse, in which his friend Prof. John E. Sweet is so important a factor, was also near his heart.

Mr. Baldwin was early brought into active relations with the Society. He served on early nominating committees, was made Manager for the term 1887–1890 and Vice-President for 1890–1892, serving five continuous and important years on the Council. But his greatest service was as Chairman of the finance committee with control over the budget of each year. He was successively re-appointed fourteen times, and his service ceased only with the changes in constitution and by-laws in 1904. He was a member of the Council's Committee which bravely faced the problem of the purchase of No. 12 West 31st Street, in 1890, when the Society had no capital to invest in such a great undertaking, except the earnest purpose of those members whom the secretary of that date had stimulated to the point of venturesomeness. The bonds issued as a part of the financial scheme were all redeemed and the second mortgage paid off within the period of Mr. Baldwin's activity. He worked very hard for two winters over a plan to develop meetings of the junior members of the Society for their common advantage. The monthly meetings of the Society in different cities are an heritage from those efforts.

Mr. Baldwin was a sound and straight thinker, a man of great power of application, an analytical reasoner, a diligent and painstaking worker. Tall and commanding of figure, he had the grace, refinement and broad culture of the scholar. His inventive mind was always at work, adding labor-saving devices as well as improvements to whatever interested him, and his pleasing personality intensified the impression of good fellowship by which he put every one at ease. He inspired such confidence in his integrity that he was constantly

sought as an adviser. He was at one time a member of the American Society of Civil Engineers and of the American Institute of Mining Engineers. He was very active also with his friend J. F. Holloway in the buildimg up of the Engineers Club, and was one of its four honorary members.

Mr. Baldwin died at the home of his daughter on January 5, 1910, after several years of physical weakness, although of clear mental capacity, and a personality active in the days of the up-building of the Society has gone to his reward.

CHARLES B. DUDLEY

Dr. Charles B. Dudley died at his home in Altoona, Pa., on December 21, 1909. He was born July 14, 1842, at Oxford, Chenango Co., New York, where he received his early education. In 1862 he enlisted as a private soldier in the 114th New York Volunteers and fought in seven battles, finally receiving a severe wound at the battle of Opequan Creek in 1864. Returning from the war in 1865, he prepared at the Oxford Academy and Collegiate Institute to enter Yale, from which he received the degree of A. B. in 1871; and in 1874, the degree of Ph.D. His graduation thesis, On Lithium and a Glass made with Lithium was published in full abstract in the Proceedings of the American Association for the Advancement of Science.

The following year he became assistant to Dr. George F. Barker, Professor of Physics at the University of Pennsylvania, and during this time published in the Franklin Institute Journal some translations of German technical papers. After a month spent as teacher of sciences at Riverview Military Academy, Poughkeepsie, N. Y., in November 1875 he went to Altoona to take up his life work as chemist of the Pennsylvania Railroad.

When Dr. Dudley entered upon his new task, no railroad had a chemist as a regular employee, although many had occasional chemical work done, and the whole subject of the relation between scientific knowledge and its practical use by railroads was in a very chaotic state. It would not be possible to enumerate the special investigations and studies leading to modifications of practices in daily use on railroads which have been considered since that time by the experimental department at Altoona, for the chemical part of which Dr. Dudley was responsible. That which attracted the most widespread attention, perhaps, was the study of steel rails, made in the early eighties, which gave the steel-maker as never before a view of

his product from the standpoint of the consumer and forced upon him a study of it not only for immediate output but also with an eye to the demands which service would make upon it.

Another very important line of work has been the making of specifications, perhaps the most exacting and time-consuming undertaken. Investigations have been made, furthermore, into the questions of ventilation, car lighting, steam heating of cars, disinfectants, cast iron for car wheels and other important uses, paints, long-continued tests on bearing metals, analyses of coals, water supplied both for boiler use and drinking, and explosives.

Dr. Dudley has been abroad on three important commissions: in 1886 to study oil burning on locomotives in Russia, in 1900 as a delegate to the International Railway Congress in France, and in 1909 as a delegate to the Convention of the International Society for Testing Materials in Denmark. He had been vice-president of the American Institute of Mining Engineers, and twice president of the American Chemical Society. At the time of his death he was president of the International Society for Testing Materials, as well as of the Bureau of Explosives of the American Railway Association. He was a member of the English, French and German Chemical Societies; of the Iron and Steel Institute of Great Britain; of the Verein deutscher Eisenhüttenleute; the American Society of Civil Engineers; the American Institute of Electrical Engineers; and social clubs in Philadelphia, Washington and New York. He was also much interested in the Altoona Mechanists' Library.

Dr. Dudley was a member of the Research Committee of the Society.

WILLIAM METCALF

William Metcalf was born at Pittsburg, Pa., September 3, 1838 and educated there and at the Rensselaer Polytechnic Institute, from which he was graduated in 1858. Immediately after graduation he went into the employ of the Ft. Pitt Foundry, as draftsman and afterwards as superintendent, and later joint proprietor. One of his chief duties as superintendent was the casting of mortars, shells and guns for the United States Government during the Civil War, at a time when the largest cast-iron guns ever made were being cast at this foundry.

Soon after the close of the war, Mr. Metcalf bought an interest in the firm of Miller, Barr & Parkin, later Miller, Metcalf & Parkin, and after incorporation in 1889 known as the Crescent Steel Company.

This company engaged in the manufacture of fine steel. In 1895, Mr. Metcalf retired from the Crescent Steel Company and in 1897 organized the Braeburn Steel Company, of which he was principal stockholder and president at the time of his death, December 5, 1909. His book, Steel, a Manual for Steel Users, is regarded as an authority.

Mr. Metcalf was a member and one-time president of the American Society of Civil Engineers and the American Institute of Mining Engineers, and first president of the Engineers' Society of Western Pennsylvania. He had served as vice-president of the American Iron and Steel Association, and was a member of the Institution of Civil Engineers of Great Britain. In addition he was a member of the Duquesne Club of Pittsburg, and the Century Association and Engineers' Club of New York, and was actively engaged in hospital and charity work. He was appointed by the United States Government one of seven appraisers for the condemnation of the property and franchise of the Monongahela Navigation Company, in March 1897.

Mr. Metcalf entered the Society in 1880 and was its vice-president from 1882 to 1884.

PERSONALS

Geo. M. Brill and Horace C. Gardner have formed a partnership under the name of Brill & Gardner, continuing the engineering and architectural practice heretofore conducted by Mr. Brill. Mr. Gardner was formerly manager of the construction and mechanical departments of Swift & Co. The offices will be in the Marquette Building, Chicago, Ill.

J. Ansel Brooks delivered an illustrated lecture on Aerial Navigation at the January 11 meeting of the Brown University Engineering Society, formerly known as the Brown University Society of Civil Engineers.

Prof R. C. Carpenter and E. H. Faile announce a partnership for the practice of engineering, with office at 68 William Street, New York. This change will not prevent the continuation of his duties at Cornell University by Professor Carpenter, who will take up his work of instruction again at the expiration of his present year's leave of absence from the University. Mr. Faile was formerly associated with the City Investing Company, New York.

A. C. Dinkey has been made a member of the board of trustees of the Carnegie Library, Pittsburg, Pa.

George W. Dunham has severed his connections with the Hudson Motor Car Company, and is now occupying the position of vice-president and consulting engineer, with the Chalmers-Detroit Motor Company, Detroit, Mich.

Wm. Wood Estes, of Providence, R. I., has taken a position with the chief engineer of the Rhode Island Co.

Edwin. J. Haddock has given up his office in Columbus, O., to accept a position with the Tennessee Coal, Iron and Railroad Company, as mechanical and structural engineer in the coal mining department.

Sir R. A. Hadfield has been elected a vice-president of the Faraday Society of London, for the next session, 1909-1910.

John T. Horton, formerly manager of the Dobbie Foundry and Machine Company, New York, has opened an engineering office at 95 Liberty Street, New York, specializing on machinery and appliances for hoisting and handling material and contractor's equipment.

Frederick H. Keyes, formerly general manager of the Robb-Mumford Boiler Company, has associated himself with Messrs. Timothy W. Sprague, Henry D. Jackson and others, to conduct a general consulting engineering practice in New York.

Walter Laidlaw, originally identified with the Laidlaw-Dunn-Gordon Co., Cincinnati, O., and general manager of the Snow Steam Pump Works, Buffalo, N. Y., is hereafter to be located at the New York office of the International Steam Pump Co.

J. W. Lieb, Jr., was elected vice-president of the National Society for the Promotion of Industrial Education at its annual convention at Milwaukee, December 2–4, 1909.

Walter M. McFarland, acting vice-president of the Westinghouse Electric and Manufacturing Company, East Pittsburg, Pa., has resigned to engage in other business.

W. K. Millholland, until recently secretary of the international Machine Tool Company, Indianapolis, Ind., has formed the W. K. Millholland Machine Company, Indianapolis, of which he is president.

Charles E. Rogers has become connected with the Johannesburg, South Africa, office of Fraser & Chalmers, Ltd. Until recently he was associated with the Melbourne, Australia, office.

L. H. Thullen, who has conducted a consulting practice in electrical engineering in New York, has recently accepted the position of chief engineer with the Triumph Electric Company, Cincinnati, O.

W. R. Warner presented a paper on Egypt and the Pyramids at the January 11 meeting of the Cleveland Engineering Society.

Earl Wheeler has resigned his position as director of the department of electrical and mechanical engineering, Engineer School, United States Army, to become electrical and mechanical engineer of the Electric Speedometer and Dynamometer Manufacturing Company, 1317-1319 New York Ave., Washington, D. C

THE ELECTRIFICATION OF TRUNK LINES

By L. R. Pomeroy, New York
Member of the Society

It is assumed from a physical and mechanical viewpoint, that electric traction can meet all the demands and requirements of railroad service. Therefore, whether electricity will replace steam traction or not is entirely a commercial problem.

THE COMMON DENOMINATOR—COMMERCIAL CONSIDERATIONS.[1]

2 It may be stated at the outset that whatever system of electrification is adopted, a very large outlay has to be faced and no case for electrification can be made out unless an increase in net receipts can be secured sufficient to more than pay interest on the extra capital involved. This increase may be brought about either by decreasing the working expenses for the same service, by so modifying the service as to bring in a greater revenue, or by a combination of these.

3 However, there is hardly a steam road in existence to-day which does not have divisions or sections, where distinctly local traffic can be handled more profitably by light, comparatively frequent electric service, than as now, with heavy steam trains. Both steam and electric service can be operated over the same tracks without detriment or embarrassment to either. In so doing each kind of

[1] Commenting on the problem of electrification of the Central Pacific over the Sierras, Mr. Kruttschnitt says: "Eastern critics may be inclined to the opinion that we are dallying with this matter. We have found that it pays well to make haste slowly with regard to innovations. Electrification for mountain traffic does not carry the same appeal that it did two years ago. Oil burning locomotives are solving the problem very satisfactorily. Each Mallet compound locomotive, having a horsepower in excess of 3,000, hauls as great a load as two of former types, burning 10 per cent less fuel and consuming 50 per cent less water."—*Wall Street Journal.*

The American Society of Mechanical Engineers.
All papers are subject to revision.

service would be approximately handled in a manner best suited to the conditions of each.

4 The fundamental principle, based on the present state of the art, seems to be that if you cannot accomplish something by means of electricity that is now impossible by steam traction, there is nothing to justify the change; the mere substitution of one kind of power for another, merely to obtain the same result, is not commercially warranted.

5 There are certain inherent advantages in electrical operation that have shown up very well, because the increase in business has absorbed the increased interest account, but these cases hardly apply to trunk line conditions as the law of induced travel has no bearing on freight train operation, the principal business of trunk line roads.

6 In heavy work the limiting feature of the steam locomotive is the boiler, and the maximum adhesion can be utilized only at low speeds. For example, a 2-8-0 locomotive with 180,000 lb. on the drivers, has a tractive force, at 10 miles per hour, of about 40,000 lb. or 4.5 to 1. At 30 miles per hour the tractive force becomes 13,250 lb. or 30.2 to 1. As tractive force governs the tonnage hauled, the ability of the electric locomotive to utilize almost indefinitely power proportional to the maximum adhesion and produce a drawbar pull entirely independent of the critical speed of a steam locomotive, as limited by the boiler, is a marked feature.

7 In heavy grade work the ability to increase the speed shows up favorably to the electric locomotive as enlarging the capacity of a given section, but here also the business has to be sufficient to absorb the increase in fixed charges.

8 With steam locomotives a coal consumption, when running, of 4 to 5 lb. per i.h.p. hr. really means 6 or 7 lb. at the rail, when the losses due to firing up, laying by in yards and sidings, blowing off at the pops, and consumption of the air pumps, are taken into account. Whereas, under electric operation, with an efficiency of 65 to 70 per cent between the power house and the rail, a coal consumption of 4 lb. per kilowatt hour at the rail can be counted on.

9 The writer is informed that the Metropolitan Street Railway station (1903) with a 40 per cent load factor, produced power, at the switchboard, at the rate of 4.7 mills per kilowatt hour (or 3.5 mills per horsepower hour), and with a load factor of 55 per cent which prevails in the winter time, the cost is at the rate of 4.43 and 3.3 mills respectively. These costs cover all expenses and repairs except

fixed charges. The coal consumption is 2.9. lb. per kilowatt and 2.16 per horse-power hour.

10 L. B. Stillwell is authority for the statement that the Interborough is producing power at the rate of 2.6 lb. of coal per kilowatt hour or 3 lb. at the drawbar.

11 Another authority gives the following figures for the elevated roads for cost of power, \$0.005 per kilowatt hour at the switchboard, \$0.0066 at the third rail shoes, or \$0.0089 at the rims of the drivers. These figures are exceptional and hard to duplicate and as the fixed charges are not included, the writer would consider $1\frac{1}{4}$ cents per kilowatt hour at the rail a conservative figure, and will use this cost in the following computations.

RELATIVE COST OF COAL FOR STEAM AND ELECTRIC OPERATION

12 It may be fair to assume that where average coal is used, we can count on about \$2.25 per ton for locomotive coal on the tender, while a much cheaper grade can be used in the power house, costing, with modern coal handling facilities, about \$1.50 per ton. At this rate the relative difference in the cost of coal at the rail would be represented by the following figures:

Electric Power Station $\dfrac{2.5\text{ lb}\ldots}{50\%\text{ off.}} \times \$1.50$	\$7.50
Steam Locomotive $7 \times \$2.25$	\$15.75

or 50 per cent in favor of electricity. The following results of the Mersey Tunnel operation are pertinent: Under electric operation one ton of coal at \$2.10 yields 2.29 ton miles at $22\frac{1}{2}$ miles per hour, while with steam, one ton of coal, at \$3.84 yields 2.21 ton miles at $17\frac{3}{4}$ miles per hour. The difference amounting to 55 per cent is in favor of the electric operation, thus:

$$\left[1 - \frac{2.10}{3.84}\right] \times \frac{22.5}{2.29} \div \frac{17.75}{2.21} = \left[1 - \frac{2.10}{3.84}\right] \times \frac{22.5 \times 2.21}{2.29 \times 17.75} = 55\%$$

13 On mountain grades or in heavy freight service, where the boiler of the freight locomotive is forced to the limit, and the boilers are designed for this particular purpose, the showing is still more favorable to the electric side. Especially is this true when the steam locomotive is detained on side tracks for as long a period as it takes to make the run, which is very frequently the case, since under these conditions the cost for fuel becomes a larger proportion of the

total operating expense. A 2-8-0 locomotive with 50 sq. ft. of grate surface burns 300 lb. of coal per hour while lying on side tracks. Reports from Mallet locomotives indicate that from 600 to 800 lb. are burned per hour under the same conditions.

14 The cost of a unit of power with the steam locomotive becomes relatively higher under maximum than minimum boiler demands, while with electricity the cost per unit is at a uniform rate, whether working under extreme or light power demands.

For example:

15 *Case 1.* A consolidation (2-8-0) type locomotive with 180,000 lb. on 57 in. drivers, 50 sq. ft. of grate surface, working under maximum conditions on a $1\frac{1}{2}$ per cent grade, would burn 150 lb. of coal per sq. ft., of grate surface per hour and evaporate from 12 to 15 lb. of water per sq. ft. of heating surface per hour. Under these conditions the cost per 1,000 ton miles would figure out as follows:

$$\frac{F \times \text{price per ton} \times R \times 1000}{2000 \times \text{m.p.h.} \times E \times TF} = \text{Cost per 1,000 ton miles}$$

where F = coal per hour (150 lb. × 50 sq. ft. of grate surface).
R = resistance to be overcome [(grade per cent × 20) plus 6].
E = 80 per cent efficiency to cover losses such as cleaning fires, idle time while under steam, cylinder condensation, air pump consumption, etc.
TF = tractive force, in this case 180,000 lb. on drivers ÷ 4.5 = 40,000 lb.

Substituting these values, the formula becomes

$$\frac{7{,}500 \text{ lb.} \times \$2.85 \times 36 \times 1{,}000}{2{,}000 \times 10 \times 80\% \times 40{,}000} = \$1.20$$

If the same service is handled by electric locomotives the cost on a similar basis becomes:

$$\frac{R \times (\text{watt hr. per ton mile}) \times 1{,}000 \text{ tons} \times \text{price per kw. at the rail}}{1{,}000 \text{ watts}}$$

$$= \frac{36 \times 2 \times 1{,}000 \times \$0.01\frac{1}{4}}{1{,}000} = \$0.90$$

17 If locomotive coal is taken at $1.70 per ton (the price in eastern Pennsylvania for low grade soft coal), the cost for coal for locomotives under the foregoing conditions would be:

$$(a) \quad \text{Steam,} \ \frac{\$1.20 \times 1.70}{2.85} = \$0.716$$

(*b*) Electric current reduced to 1c. per kw. hour at the rail:

$$\frac{0.90 \times 1\text{c.}}{1\frac{1}{4}\text{c}} = \$0.72$$

18 *Case 2.* An express passenger locomotive of the Atlantic (4-4-2) type, with the following data: Cylinders 21 by 26 in., boiler pressure 200 lb. per sq. in., weight on drivers 102,000 lb., heating surface 2,821 sq. ft., grate surface 50 sq. ft., rate of combustion 150 lb. per sq. ft. of grate surface per hour, speed 70 miles per hour. Figuring as in Case 1.

$$\frac{7{,}500 \times 2.85 \times 20 \times 1{,}000}{2{,}000 \times 70 \times 80\% \times 5{,}350} = \$0.71$$

Under electric conditions we have

$$\frac{20 \times 2 \times \$0.01\frac{1}{4} \times 1{,}000 \text{ tons}}{1{,}000 \text{ watts}} = \$0.50$$

or 28½ per cent less.

19 If coal is taken at \$1.70 per ton, as in Case 1, the cost is reducd from \$0.71 to \$0.42, making the difference slightly in favor of steam.

20 These figures apply only to the conditions named, and average conditions on an undulating profile, when coasting is occasionally possible. With the benefits of momentum grades, also, the figures would be relatively less, but the electric locomotive would respond and benefit accordingly, so that the percentages would be approximately the same.

21 When steam locomotives are loaded to their capacity, as is generally the case where tonnage rating is practiced, the rate of combustion of 150 lb. of coal per square foot of grate surface per hour, will still hold good and remain constant, the tons hauled being the variable, responding or being modified by the speed or physical conditions of the road.

SAVINGS CLAIMED FOR ELECTRIFICATION

22 In view of the foregoing the following extract from an article by Mr. C. L. De Muralt will be of interest. The figures are from the annual report of 1903 of the roads named.

COST OF OPERATING TRUNK LINES

	P. R. R.	N. Y. C.
Fuel for locomotives	$6,000,135	$4,635,877
Water " "	335,286	295,583
Other supplies for locomotives	382,548	334,673
Wages: Engine men and roundhouse men	5,716,848	4,928,443
Other trainmen	4,442,127	2,991,335
Switchmen, flagmen and watchmen	3,900,427	2,511,552
Other expenses of conducting transportation	14,540,542	11,607,538
Repairs to locomotives	4,412,983	3,608,972
" other equipment	10,674,726	5,661,992
" roadbed	8,542,935	6,145,341
" structures	4,122,018	2,454,691
General expenses	1,858,319	1,786,494
	$64,928,894	$46,962,491

23 Mr. De Muralt then applies the figures found during the course of his investigation, which would lead to the following reductions if electricity was adopted as a motive power.

	P. R. R.	N. Y. C.
Fuel 10 per cent	$600,013	$463,388
Water saved entirely	335,286	295,583
Other supplies 50 per cent.	191,274	167,336
Wages, enginemen, etc., 25 per cent	1,429,212	1,207,361
Repairs to locomotives	2,206,492	1,804,486
Total amount saved	$4,762,277	$3,942,154

24 The saving in water alone capitalized at 5 per cent equals $6,750,000 for the former and nearly $6,000,000 for the latter road. As large as these alleged savings are, yet they would not amount to more than 2½ to 3 per cent on the necessary increase in capital to electrify the roads on which the foregoing savings apply.

25 While the first cost for power stations and electric equipment represents a large outlay, yet such items as the cost for repairs of locomotives and shops, expensive hostlering at terminals, coaling and water stations, and the incidental labor charge and repairs thereto will, in the aggregate, be materially reduced. The comparative saving in repairs will be indicated by the following figures:

Repairs	Steam	Electric
Boiler	20%	0%
Running gear	20%	20%
Machinery	30%	15%
Lagging and painting	12%	5%
Smoke box	5%	0
Tender	13%	0
	100%	40%

OTHER COMPARISONS BETWEEN STEAM AND ELECTRIC LOCOMOTIVES

26 It is further claimed that, with electric operation, greater mileage is possible with the electric locomotive and that fewer units are necessary to perform the same service. Great stress is laid on the fact that the ordinary freight locomotive makes only 3,000 miles per month, or 100 miles per day, against which is put forward

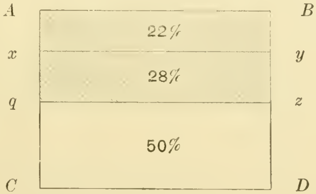


FIG. 1 DIAGRAM SHOWING DIVISIONS OF LOCOMOTIVE WORKING DAY

the ability of the electric locomotive to perform practically continuous service, suggesting the propriety of comparing electric and steam operation on the basis of ton miles per annum each is able to make and also the relative weight on driving wheels and not their total weight.

27 The operating efficiency of a steam locomotive in freight service is so low, averaging about 3,000 miles per month, that it is generally thought due to limitations, *per se*, in the locomotive, whereas it is mainly due to operating and traffic conditions, which limitations would apply with equal force to the electric locomotives, so that, barring some increase in speed, the electric locomotive can make no greater mileage than its steam competitor in equivalent service, consequently its splendid ability to perform almost continuous service cannot be realized in practice for reasons aforesaid.

28 Let the rectangle *A B C D* represent a day of 24 hours the shaded area *A B x y* that portion of the time for which the mechanical department is responsible = 22 per cent; the area *x y q z*, the average

time the locomotive is performing useful work = 28 per cent—*i. e.*, actually pulling trains, 3,000 miles per month, 100 miles per day; while the portion of the diagram bounded by $q\ z\ C\ D$, the period or balance of the time that the locomotive is under steam, with crew, and ready to go, and represents the time at terminal yards, side tracks and awaiting orders, etc. = 50 per cent.

29 It is just here that our electrical friends make the great mistake of claiming "greater capacity" for the electric locomotive over its steam equivalent. It is conceded that under electric conditions the area $A\ B\ x\ y$ may be reduced as much as one-half and perhaps, owing to greater speed, the area $x\ y\ q\ z$ may be increased, but the "lost motion" period due to traffic and operating causes will be relatively the same for both. The percentages are from an actual three months' test on a trunk line reported in 1904 in the proceedings of the American Railway Master Mechanics Association by the committee on time service of locomotives.

30 The only cases where electric operation is commercially justified is in congested local passenger situations where the conditions closely approach those of a "moving sidewalk" and the records show that these cases have been profitable only when a large increase in business has been realized.

31 A modern Atlantic (4–4–2) type locomotive weighs, including tender, 321,620 lb. with a maximum tractive force of 23,500 lb. The ratio of total weight to tractive power is 133 to 1. The New York Central electric locomotive, with a total weight of 192,000 lb. and a tractive effort of 27,500 lb. has a ratio of 7 to 1. The comparison is still more favorable for electric freight locomotives where the entire weight is on the driving wheels.

POWER STATION CAPACITY

32 The impression is quite prevalent that if 100 steam locomotives are required to operate a certain division, if operated electrically, a power station capacity the equivalent of 100 locomotives would be necessary, whereas the generator capacity, barring the installation of spare units, would be of such size as to meet the average load. This average can be determined by laying down a train sheet, from which the load at any hour in the day can be seen and the peaks located.

33 For ordinary computations the number of trains to provide for is, approximately:

$$\frac{\text{The total train miles per hour}}{\text{Mean speed}}$$

This formula is the result of cancellation from the following:

(*a*) h. p. days ÷ Aggregate h. p.

That is:

$$(b)\quad \frac{5{,}280 \times (\text{Dis. miles}) \times (\text{No. trains}) \times (\text{Tons}) \times R}{47{,}520{,}000 \text{ ft. lbs. in 1 day}}$$

$$\div \frac{\text{Tons} \times R \times \text{m.p.h.}}{375}$$

R = resistance due to gravity, + resistance due to speed, + curve resistance. Transposing and cancelling:

$$(c)\quad \frac{\text{Dis. miles} \times \text{No. trains}}{24 \times \text{m.p.h.}}$$

For illustration take a typical case: Distance 183 miles.

LOAD		AVERAGE SPEED	
37 Freight Trains	at 15 m.p.h.	37 × 15 m.p.h. =	555
22 Expresses	at 50 m.p.h.	22 × 50 m.p.h. =	1,100
21 Locals	at 30 m.p.h.	21 × 30 m.p.h. =	630
80 Trains total.		80	2,285

2,285 ÷ 80 = 28 average m.p.h.

$$\frac{80 \text{ trains} \times 183 \text{ miles}}{24 \text{ hr.} \times 28 \text{ m.p.h.}} = 22 \text{ trains.}$$

34 For more accurate work a train sheet should be made either with miles as ordinates and time as abscissæ, or one with trains as ordinates on a time (abscissa) base.

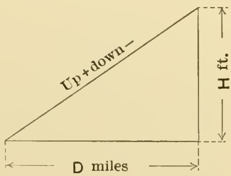
35 Relative to *R* (*i.e.*, resistance) for gravity; divide the profile into sections, one for each change in grade, plus or minus as thecase may be:

$$\frac{H}{D \times 52.8} = \text{Per cent grade.}$$

Each 1% grade = 20 lb. = R

R for curves 0.56 lbs. per degree.

$$\text{R for level sections} = 2 + \frac{\text{m.p.h.}}{4}$$



36 Consider the example of a road or division 100 miles long on which a given train requires 2,000 h.p. to keep it in motion. If 20

cars take a maximum of 100 h.p. each, the electrical conductors and distributing apparatus will never be required to deliver more than 100 h.p. at any one point. If on the other hand, the entire traffic of the line must be concentrated in a single train, the electrical conductors and distributing apparatus must deliver the full 2,000 h.p. at each and every point. In other words, with the concentrated load, the capacity of the distributing apparatus at each and every point must be 20 times as great as the capacity when 20 cars are used to give the same total load. Electric traction has proved its superiority for distributing loads, but concentrated loads are still handled almost exclusively by steam locomotives.

SOME ADVANTAGES OF ELECTRIC LOCOMOTIVES

37 In the annual report of the P. R. R. (1903) the president states "That the congested condition of your system has brought about a large increase in the ton mile cost, which for 1903 was 25 per cent greater than for 1899. In order to prevent the increase in ton mile cost, it is necessary to move freight trains faster in places where traffic is dense, and for such purposes the electric locomotive is most efficient."

38 With steam locomotives the most economical average speed, for freight service, is 12 to 15 miles per hour, where there is ample track space for the free movement of trains. With a dense traffic this free movement can only be obtained by a higher speed and if the large train tonnage be maintained, more horse-power is required of the engine and boiler. It is difficult to increase the size of steam freight locomotives without resorting to the Mallet compound articulated type, and here we have the equivalent of two locomotives in one machine.

39 With the electric locomotive it is possible to develop a much greater horse-power and a large percentage of overload at the time when needed and do it more economically than with steam. The New York Central electric locomotive has a maximum peak horse-power of 3,000, which is 25 per cent above normal. This maximum is about double the power which can be obtained from the New York Central standard Atlantic (4–4–2) type locomotive. Similar proportions can be obtained for electric freight locomotives and their size and power are not limited by boiler capacity. If the steam locomotive is capable of developing 30,000 T. F. at the drawbar at 12 m.p.h or

$$\frac{30{,}000 \times 12 \text{ m.p.h.}}{375} = 960 \text{ h.p.}$$

and it is required to increase the speed of the train to 20 m.p.h. and maintain the same tonnage, then 1,600 horse-power will be required, which means the employment of a much larger locomotive or double heading.

40 The advantage of the overload capacity on short mountain grades or for strategic peaks is one of the strong points in favor of the electric machine and would make electric operation applicable to special cases rather than a universal substitute, in the broad light of commercial considerations.

GENERAL CONCLUSIONS

41 Our conclusion, from this survey of the situation, is that the rapid development of suburban passenger traction by electricity will require large power houses at large cities and these can gradually be made sufficient for working the line on further stretches in each direction, handling congested terminals, or used where commercially practicable, until it may be desirable to electrify the entire division.

42 Electric operation as compared with steam shows to greatest advantage in urban and suburban passenger service. Here, if multiple unit trains are employed, so that a considerable fraction of the total weight is carried on the driving wheels, thus permitting a high rate of acceleration to be used, a schedule speed quite impracticable in steam operation can be maintained. Moreover, a more frequent service can be given without a proportional increase in expense, whilst in times of light traffic small trains can be run, the energy consumption per train in such service being almost in proportion to the number of coaches. The law of induced travel, however, applies to urban and suburban passenger service, but does not hold for trunk lines and especially freight service.

TO DETERMINE WHETHER IMPROVEMENTS ARE JUSTIFIABLE

43 Under trunk line conditions the only thing that interests railway managers is the traffic available at the present, relatively speaking; the future is too indefinite to be capitalized to any great degree in advance. It is more in the line of insurance companies to "capitalize expectations."

44 In grade revision the authorization for expenditure is based on the saving in train miles capitalized. The following is a concrete case from a Western road, or rather the summation of the engineers'

report as to just what the proposed rearrangement would amount to. The rate of 50 cents per train mile is to cover those items of cost directly affected by the change.

$$\left.\begin{array}{l}\text{No. of}\\ \text{trains per}\\ \text{day—7}\end{array}\right\} \times \left[1 - \frac{\text{1,350 tons present conditions}}{\text{1,600 tons proposed}}\right] \times \left\{\begin{array}{c}\text{Div. of}\\ 225\\ \text{Miles}\end{array}\right\} \times 50\text{c.} \times \left\{\begin{array}{c}365\\ \text{days}\end{array}\right\} = \$45{,}990.$$

45 Under the circumstances it will be seen that the value of 1 per cent reduction in train mileage per mile per train, amounts to $1.95 per annum. The total amount capitalized at 5 per cent equals $919,800. In some such manner the steam railroad manager arranges the proposition of the electric scheme and decides accordingly.

SOME EXAMPLES

46 In a paper before the American Society of Civil Engineers by W. J. Wilgus, some interesting data concerning New York Central operation were given:

Cost of coal per 2,000 lbs. anthracite steam loco., terminal service	$4.46
" " bituminous coal, road service	3.12
" " " " power station	2.72
Water per 1,000 gallons:—	
Power station	13.5 cts.
Road service	5 "

47 The cost of current, when power station designed load is attained, is 2.6 cents per kilowatt hour delivered at contact shoes. This includes all operating and maintenance costs, interest on the electrical investment required to produce and deliver current, depreciation, taxes, insurance and transmission losses. The following table summarizes the data:

Items	Operating Costs	Fixed Charges	Total
Power Station	0.58 cts.	0.44 cts.	1.02 cts.
Transmission Losses	0.19 cts	0.15 cts.	0.34 cts.
Distribution Systems			
Substations	0.32 cts.	0.92 cts.	1.24 cts.
Totals	1.09 cts.	1.51 cts.	2.60 cts.

48 In a discussion by G. R. Henderson (page 102, Vol. LXI, Trans. A. S. C. E.), are given road service costs per 1,000 car ton miles:

	Steam	Electric
Supplies	$2.03	$1.37
Wages	0.28	0.31
Interest, depreciation, and repairs to locomotive	0.46	0.34
	$2.77	$2.02

49 The item "Electric Supplies" is composed of operating expenses and fixed charges and may be analyzed thus:

53.3 kw. hour at $0.0109, $0.58 operation
52.3 kw. " " 0.0151, 0.79 fixed charges
52.3 kw. " " 0.026, 1.37

$$\left[\text{Fixed charges} = \left(\frac{0.79}{1.37}\right) = 57 \text{ per cent of operating expenses}\right]$$

The brackets are ours. The difference in cost between steam and electric traction in road service is $2.77 − 2.02 = $0.75 per 1,000 car ton miles.

50 The fixed charges on the power plant and the transmission system are $0.79 per 1,000 car ton miles, or about the same as the saving, so that if the train movement were but one-half the assumed amount (averaging 6,000 horse-power at the rails, or 6,000 kilowatts at the station) the cost for electric service would be slightly higher than for steam, or $2.81 as against $2.77 per 1,000 car ton miles.

51 The Manhattan Elevated, with about 38 miles of road, was electrified at an expense of $17,000,000. The operating ratio, under electric conditions, has been reduced from 61 to 46 per cent of gross receipts. The net result after taking care of the increased capital, etc., shows 15 per cent profit, but it is a significant fact that the increase in business was 46 per cent (carrying about 250,000,000 people per annum, 690,000 per day average, or 28,800 per hour).

52 There has just been reported the four years electric operating results of the Mersey tunnel road connecting Liverpool and Birkinhead. The net profit, allowing interest, etc., on the increased capital due to electrification, amounted to 15 per cent, but it took an increase in traffic of 55 per cent to make this operating result possible. Ton miles increased from 43 to 67 million, or 55 per cent. Total expenses, including interest on electric capital (but not depreciation) equal $0.586 per ton mile. Interest equals $0.106 per ton mile, or 22 per cent of operating expenses.

53 President Harahan of the Illinois Central reports the results

of the investigation that has been made relative to the proposed electrification in the following words:

54 "Our suburban traffic is the only service which would in any degree be adapted to electric operation, but even in this particular service it can be readily shown to be unjustifiable at the present time. I submit below a statement of the results which are estimated to accrue if the entire suburban service were electrified, compared with the present steam operation:

"Results of Operation of Suburban Business at Chicago for Fiscal Year ending June 30, 1909:

Gross earnings		$1,056,446
Operating expenses (82.9%) plus taxes		946,734
Net revenue		$109,712
"Estimated Results Under Electrification:		
Gross earnings		$1,056,446
Operating expenses (66%)	$697,254	
Taxes	74,427	
		$771,681
Net revenue (electric operation)		$284,765
Net revenue (steam operation)		109,712
Increase		$175,053
Estimated cost of electrification		$8,000,000
Interest and depreciation 10%		$800,000
Saving in operation under electrification		175,003
Deficit		$624,947

55 "Our suburban traffic is not sufficiently dense to warrant the expense necessary to electrify these lines, and it is evident from the foregoing figures that even under electrification there would not be an increase in traffic sufficiently large to offset the annual loss from operation. It simply proves that under present conditions of cost of electrification of steam railways, where it means a replacement of a plant already installed, and serving the purpose, it is not justifiable to electrify either in whole or in part your Chicago terminals at this time."

56 The surburban district of the Illinois Central covers about 50 miles of road and carries in round numbers 15,000,000 surburban passengers per annum, or an average of 41,150 per day, or 1,700 per hour. An increase of 100 per cent in earnings would not enable the road to break even.

57 The Railway Age Gazette, in commenting editorially on Mr. Harahan's statement, says:

58 "It may be accepted as conclusively demonstrated that the New York Central and the New Haven roads are moving trains by electricity more economically than they moved them by steam in their suburban district. To enable this to be brought about, however, extremely heavy capital costs had to be assumed and the charges on these capital costs make the entire operating cost, including overhead charge, far higher than it used to be in the days of steam operation.

59 "For example, a standard express train of eight cars on the New Haven road pulls out of Grand Central station headed by two half-unit electric locomotives, each of which cost very nearly $40,000. The capital cost of the motive power of this train is in excess of $75,000 [the interest and depreciation amounting to $20 per day]—the brackets are ours. The cost of motive power at the head of a similar New York Central passenger train operated by electricity is about one-half this sum. Moreover, it will be recalled that Mr. Wilgus estimated that the direct costs of electrical equipment represented only one-fourth of the total charges attendant upon electricity. The cost of making everything ready and safe for this kind of operation is far greater than the highest estimates are apt to contemplate."

60 From a report of the Electrical Commission of the State of Massachusetts the following extracts are taken (letter of C. S. Mellen, president of the New Haven road):

61 "We believe we are warranted in saying that our electric installation is a success from the standpoint of handling the business in question efficiently and with reasonable satisfaction, and we believe we have arrived at the point where we can truthfully say that the interruptions to our service are no greater, nor more frequent, than was the case when steam was in use. But we are not prepared to state that there is any economy in the substitution of electrical traction for steam; on the contrary, we believe the expense is very much greater."

62 The Boston & Albany Railroad Company reports the result of their study and estimates the requirements as follows: A power station of 6000 kilowatts will be necessary, with storage batteries to handle the peak load. The total cost of the installation is estimated at $4,000,000, and the interest, taxes, and depreciation at 9 per cent, or about $400,000 per annum. A stock argument for electric operation is the saving to be made in operating expenses, but concerning this the following statement is made:

63 "Some slight economies would accrue in the transportation

expenses under this operation, which would be substantially absorbed by the additional expenses to be incurred for the maintenence of the additional apparatus installed, and the net economies would be so small as to be inappreciable in the consideration."

64 Another stock argument of the advocates of electric locomotives is the growth of traffic which is supposed to result from electric operation. This argument is met as follows in the report:

65 "Considering now the possibilities of increasing the traffic, the statistics of the B. & A. R. R. show substantially the following number of passengers handled in the above territory per annum:

1891	4,552,918	1899	3,897,364
1894	4,799,578	1907	4,435,841

66 "The absence of any material increase in traffic is probably due to the fact that the circuit is occupied as a high class residential district not susceptible of rapid subdivision of property, and more particularly to the fact that suburban lines are being rapidly extended into all such outlying districts and afford a more advantageous means of collecting and distributing local travel through the commercial and residential districts than could possibly be afforded by a railroad constructed and operated upon private right of way and devoted largely to long haul operations."

EXAMPLE TO ILLUSTRATE A CONCRETE CASE

67 The following illustration representing a concrete case is selected because of its elementary character, more especially as the case is so simple that all the variables affecting the comparison are eliminated and the amount of coal to perform the operation is directly known:

Conditions: trailing load 1,600 tons; average grade, 1.3 per cent.; distance, 8 miles; speed, 15 miles per hr. for electric and 14 miles per hr. for steam locomotive.

(*a*) Electric

1,600 net tons
190 Loco. (2) tons
———
1,790 gross tons

$$R = \begin{cases} 1.3\% \text{ grade} \times 20 = 26 \text{ lb.} \\ 5° \text{ curves} \quad 3 \text{ lb.} \\ \text{Level} \quad 6 \text{ lb.} \end{cases}$$

$$\frac{\text{Gross tons} \times R \times \text{Distance}}{500} = \text{kw-hr. at the rail}$$

Substituting values:

$$\frac{1,790 \times 35 \times 8}{500} = 1,000 \text{ kw-hr. (at rail)}$$

Equivalent kilowatt load at power house =

$$\frac{\text{Tons} \times R \times \text{ m.p.h.}}{500 \times \text{Efficiency } \%}$$

Where the efficiency between the rail and generators equals 65 %, substituting as before:

$$\frac{1{,}790 \times 35 \times 15}{500 \times 65\%} = 2{,}900 \text{ kw.}$$

For this particular case current can be purchased from an adjacent power house at the very low rate of one cent per kw-hr. at the rail.

At this rate the power cost per trip will be 1,000 kw. at one cent =$10.00.

(*b*) Under steam conditions we have the same as before, 1,600 net tons + weight of two locomotives, 300, or 1,900 gross tons.

The coal consumption for this particular run is 6,000 lb.

The price per ton to equal the electric cost for power, is:

$$\frac{6{,}000 \text{ lb.} \times \text{price per ton}}{2{,}000} = \$10.00.$$

Transposing:

$$\frac{2{,}000 \times 10}{6{,}000} \times \$3.33$$

But as coal for this particular case costs the road $1.70 per ton, the relative cost, coal against power, is

$$\frac{6{,}000 \times \$1.70}{2{,}000} = \$5.10$$

There is a difference in ton mile hours, in favor of the electric locomotive, due to speed and reduced gross tonnage, as follows:

$$\text{1st Electric } \frac{1{,}790 \times 8 \times 8}{15} = 7{,}640 \text{ Gross ton mile hours}$$

$$\text{2d Steam } \frac{1{,}900 \times 8 \times 8}{14} = 8{,}690 \text{ Gross ton mile hours}$$

To make the comparison correct the coal consumption of the steam locomotive should be proportioned on the ton mile hours, produced, and the cost of coal then becomes:

$$\frac{\$5.10 \times 8{,}690}{7{,}640} = \$5.80$$

Adding to the foregoing the other operating costs the relative expense becomes

(*a*) *Electric.* Power.. $10.00

Lubrication, supplies, repairs, crew at $0.1158 per 1,000 ton miles, or

$$\frac{0.1158 \times 1{,}790 \times 8}{1{,}000} = \text{..................} \quad 1.66$$

Interest and depreciation, taxes, insurance, etc., at 10%.. 1.46

$13.12

(*b*) *Steam*. Coal as above $5.80

Lubrication, supplies, water, repairs, enginemen at $0.25 per 1,000 ton miles,

$$\frac{\$0.25 \times 1{,}900 \times 8 \text{ miles}}{1{,}000} = \dots\dots\dots\dots \quad 3.80$$

Interest and depreciation at 10 % (2 locomotives)

$$\frac{\$34{,}000 \times 10\% \times 8}{365 \times 24 \times 14} = \dots\dots\dots\dots \quad 0.22$$

$9.82

Cost per trip in favor of Steam, $3.30, or 25% less

EXAMPLES TO ILLUSTRATE A CONCRETE CASE

68 The idea is all too prevalent with the public, and even with some of the bodies that have been given legal power of supervision over railway companies, that any expenditure which can be forced upon the railway companies is just so much gain for the public. Never was there a more absolute fallacy. In the long run, the cost of every bit of railway improvement must be paid for by those who buy tickets and ship freight. Economy in the administration of our railways is just as important in the interest of the general public as if the railways were actually under government ownership.

Recently *The Engineer* (London) editorially made a plea for a "common denominator" for comparison of engineering achievements, using the following illustrations:

"Thus for example, if we take Mr. Humphrey's reply to Mr. Davey's criticisms, we see that he gained a mere dialectical advantage by showing on the screen a great differential pump, and beside it an internal combustion pump, so small by comparison that he had to explain that it was not a "hooter." Both engines could deal with the same quantity of water; but the Davey engine was lifting it 1500 ft. from a mine, while the gas pump could not lift it more than about 15 ft. Indeed, it could not do the work of the Davey engine at all."

Also a comparison was drawn between the cost of working with producer gas engines and steam engines. The argument was all in favor of the gas engine, expressed in weight of fuel required per hour to develop a horse-power. But the aspect of the matter changed when it was pointed out that the coal used by the steam engine was slack, costing $1.75 per ton, while the gas producer worked with anthracite, costing over $6.25 a ton. Here the cost of fuel was the common denominator, not the weight of the fuel.

The plea concluded by saying that the common denominator should be the commercial cost. E. H. McHenry expressed the same idea when he said that "Engineering is making a dollar earn the most interest."

LUBRICATION AND LUBRICANTS

By Charles F. Mabery[1]

Non-Member

Next to the conservation of the world's fuel supply there is probably no subject of greater importance in the manufacturing world than the control of waste power caused by imperfect lubrication and needless friction. Notwithstanding the increasing interest in more economical methods, the immense losses from this source are scarcely appreciated. In his recent work on lubrication and lubricants, Archbutt stated that with considerably more than half the 10,000,000 h.p. in use in the United Kingdom of Great Britain, 40 to 80 per cent of the fuel is spent in overcoming friction, and that a considerable proportion of this power is wasted by imperfect or faulty lubrication. On account of the great abundance of cheap fuel in the United States doubtless the conditions here are even less desirable. It is safe to state that losses from this source in this country are from 10 to 50 per cent of the power employed. Not infrequently in factories where the annual expense for lubrication amounts to thousands of dollars, lubrication experts find a loss of 50 per cent, or greater.

2 The manufacturer often knows very little concerning the economic qualities of the lubricants he receives; in using them, too much is left to "rule-of-thumb" methods with little knowledge of the actual conditions of friction, the action of metallic surfaces under the dynamic stress of the transference of power, or such modified action as is produced by the intervention of a lubricating film. For example, the different effects on a journal of a soft and hard bearing may be sufficient to cause a considerable loss of power if improperly selected, and yet may escape attention. In the earlier tentative study of the conditions depended on for the results described in this paper, under such loads as 100, or 150 lb. per sq. in. of bearing surface, the grades of babbitt in ordinary use were found much too soft and yielding to sus-

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tain such work under the necessary conditions of speed and oil feed; only a very hard alloy of exceptional composition could be used. The one selected of approximately the composition, Tin, 90; Copper, 2; Antimony, 8, gave results entirely satisfactory. Then since it was desired to maintain such conditions of load and speed that any oil could be broken down at any moment, it was found necessary, not only that the journal and bearing be milled to mechanically true surfaces, but that by continued operation and repeated careful milling, even a higher degree of permanent evenness be maintained. If such be the essential conditions in precise quantitative observations, similar precautions are evidently necessary in factory operations.

3 In the earlier days of machinery lubrication before the introduction into the trade of products from petroleum, the manufacturer had little concern about viscosity and other physical constants of lubricants, for, dealing with simple oils or greases of definite composition, he could be sure of obtaining what he desired within the capacity of the materials at his disposal. Then, in the days of higher prices of manufactured products and less severe competition, imperfect lubrication was of less consequence than in more recent times when every detail of cost and loss should properly receive careful attention; and, furthermore, the principles of friction and the importance of its control were only imperfectly understood in the earlier days of lubrication. Modern high speeds and excessively heavy loads had not then to be provided for in the applications of power in manufacturing operations, or in transmission or transportation.

4 The discovery that the heavy hydrocarbons in petroleum possessed the qualities requisite for lubrication—viscosity, durability and stability under varying conditions of speed and load—was the beginning of a new era in lubrication. Methods of treatment and refining, with little or no knowledge of the hydrocarbons of which the lubricating oils were composed, and developed entirely along empirical lines, were slow in producing suitable products. The earlier methods have undergone no fundamental changes even to the present time, except in the introduction of heavier hydrocarbons from crude oil territory more recently developed. Crude oils of the Pennsylvania type containing a considerable proportion of the hydrocarbons $C_n H_{2n+2}$ have always yielded excellent light spindle oils composed for the most part of the hydrocarbons, $C_n H_{2n}$, and $C_n H_{2n-2}$. But, as we now know, this type of oils include too small a proportion of the heavier hydrocarbons for the body necessary in lubricants subjected to the great stress of heavy loads and cylinder friction. This need in heavy

lubrication led to the practice of compounding oils, or mixing with the petroleum products various proportions of the vegetable oils, such as castor or rape, and the various animal oils or greases, which so fully monopolized this field, that manufacturers were often led to believe that no other products could serve an equivalent purpose. Even since the more recent introduction of heavy lubricants from Texas and California petroleum the belief still prevails that only compounded oils can be relied on for heavy work. But with care in distillation and treatment, it is certain that heavy lubricants, well adapted for bearings and cylinders, may be prepared from those crude oils, and large quantities of such lubricants are now widely in use.

5 All experimenters with lubricating oils who have given thoughtful attention to the essential needs of lubrication have been impressed by the superiority of an ideal solid lubricant, i. e., one that should embody an equivalent of the desirable qualities of the liquid products with a greatly superior wearing quality, a low coefficient of friction, and readily convertible into a form that can conveniently be applied to the various forms of journals and bearings. Soapstone, asbestos, natural graphite, etc., do not, altogether, possess these fundamental qualities of the liquid products. Greases compounded with graphite are useful on low-speed bearings and under heavy work. Natural graphite serves an excellent purpose on cast-iron bearings, acting as a surface evener of the porous metal. On finer surfaces care is necessary that it does not collect in such quantities as seriously to scratch or abraid the journal and bearing.

6 Of all the solid bodies available for lubrication, graphite possesses the desirable unctuous quality and great durability. For general use in lubrication, graphite must be in its purest condition and in a state of extreme subdivision. Whether, in such a condition as the deflocculated form, the ultimate molecules or atoms have a certain freedom of movement, analogous to that of liquid molecules under stress of friction, or whatever explanation may be suggested of its unctuous quality, the fact remains that it possesses this quality in very high degree. Such graphite is now produced by processes discovered, perfected, and placed on a manufacturing basis by Dr. Edward G. Acheson of Niagara Falls as a part of his great work in the development of electrochemical processes. Besides his immense output of pure graphite for general commercial use, Dr. Acheson has succeeded in converting it into a new form, a deflocculated condition, that meets the requirements of an ideal solid lubricant. This deflocculated form greatly surpasses ordinary graphite in unctuous quality,

and its adaptability for prolonged suspension in water and oils renders it especially applicable to frictional conditions. Furthermore, the readiness with which it forms coherent films on journals, its great wearing qualities and the ease of the application, constitute a lubricant of extremely high efficiency.

7 Acheson graphite can be produced from any substance that contains carbon in a non-volatile form. Under the extreme temperatures of the electric furnace any and all other elements are readily volatilized. Even carbon itself is freely vaporized and its peculiar appearance in the burning carbon-monoxid is depended on as an indicator of suitable conditions in furnace operation, much as the drop in the manganese flame which shows the disappearance of carbon in the Bessemer converter.

8 As commercial products two forms of graphite are produced, the unctuous and the deflocculated modifications, the first form accompanying the production of carborundum in furnaces charged with carbon and sand, the second obtained from a charge of coal or coke alone. The first form is leafy in structure, coherent, and extremely unctuous or greasy to the touch; it is segregated and not readily disintegrated. The second form is also unctuous in a high degree, but very pulverulent and capable of extreme subdivision; it is readily converted into a deflocculated condition. This form in water forms the commercial "Aquedag," or aqueous Acheson deflocculated graphite. In combination with oils it is known as "Oildag."

9 This deflocculated graphite has peculiar properties; it remains suspended indefinitely in water, but is quickly precipitated by impurities. On account of its extreme subdivision a very small amount suspended in water serves for efficient lubrication. From numerous and long-continued trials it appears that 0.35 per cent serves an adequate purpose and that a larger proportion is superfluous. It is certainly remarkable that such a small quantity of graphite is readily distributed by water between a journal and bearing while sustaining a load of 70 lb. per sq. in. of bearing surface, and that under high-speed conditions it maintains an extremely low coefficient of friction.

10 Proper lubrication of bearing surfaces involves careful consideration of the metals composing the journal and bearing, since the influence of the metals employed has an effect even in the intervention of the best lubricating film. The materials in common use for the construction of bearings include cast iron, steel, and alloys of variable composition included under the general terms, bronze and babbitt. In high-speed work cast-iron bearings must be used with extreme care.

In the accurate adjustment necessary in machine testing of lubricants, we have found it impossible to prevent injury to the journal when using a cast-iron bearing. Results obtained by the use of bronze have not been altogether satisfactory. However, properly selected babbitt for a steel journal seems to fulfill the desired conditions most satisfactorily and it possesses a wide range of applicability. As mentioned above, satisfactory lubrication is possible only when the journal and bearing are properly machined to true surfaces, kept smooth, accidental scratches worked out, and bare spots avoided. Successful lubrication demands constant skilled attention to the condition of journals and bearings, and no factory supervision affords more desirable returns. Lubrication consists in reducing friction to the lowest increment of the power in use. A lubricant is an unctuous body that readily forms a continuous, coherent, durable film capable of holding apart rolling or sliding surfaces, and itself interposing the least possible resistance. The economic problem in lubrication depends on the use of such a lubricant under suitable conditions.

11 The lubricants in commercial use include water, oils, greases and solids. Under oils are classified the great variety of light spindle, heavy engine and cylinder products, either unmixed hydrocarbons from petroleum or compounded oils, tallow, wool grease, etc. The greases may be generally classified under a few heads depending on their consistency, which is derived from the proportion of lime or soda soaps or oleates mixed with the hydrocarbon oil as a carrier. The solid greases have already been referred to.

12 Water in itself possesses no oiliness whatever but under certain conditions in cylinders it is found to assist in imparting to the metallic surfaces an extremely smooth condition which serves materially to reduce the friction. A practical knowledge of hydrocarbon lubricants should include a knowledge of the source, that is, the crude oil from which the lubricant is prepared, since there is a wide difference in composition and properties of the oils from different oil fields. Methods of refining petroleum oils have very much to do with the quality of the products. In general terms, inferior products are obtained when the process of distillation is conducted in such a way as to produce decomposition; the best products are obtained only by careful distillation and careful treatment in refining, whereby the hydrocarbons in the refined products obtained have essentially the same composition as in the original crude oil.

13 An examination of various lubricants in the trade frequently reveals a condition of the oils indicating improper refining. For

example, it does not need the application of extremely delicate tests to show the presence of free alkali, of sodium sulphate, or of sodium salts of organic acids, any one or all of which may be injurious to metallic surfaces. One of the most exacting duties of the refiner is the treatment with caustic soda in such a manner as to remove all acid products and at the same time to avoid such an excess of caustic as will form an emulsion, which is one of the "terrors" in a refinery. An examination of a great variety of oils in the trade, such for instance as the spindle oils in use in automobile service, indicates that the best refined oils are those that contain a minute trace of alkali.

14 The ordinary methods of testing lubricating oils include determinations of the viscosity, the specific gravity, the flash and the fire temperatures. Another important property of these oils, termed oiliness or greasiness, is not so readily determined by analysis; in fact, there seems to be no accurate method for its determination; yet it is readily distinguishable and has much to do with the efficiency of all lubricating oils. Concerning the most efficient methods of testing lubricating oils various opinions are expressed by different authors. Redwood, in his work on petroleum and its products, asserted that the viscosity of an oil is the best guide to its lubricating value since it enables the consumer to select oils similar to those that have afforded him the best practical results. He alludes to the close relationship between viscosity and the laws of friction of liquids. In comparing the use of viscosity with observations on the behavior of lubricants on a frictional testing machine, he states that he was unable to obtain satisfactory results with any machine at his disposal. His conclusions in general were that in the present state of our knowledge the indications afforded by testing machines are wholly misleading, and this led him to attach especial importance to a good system of testing viscosity. He refers to the opinion of Thurston that any oil should be tested on a machine under the conditions of load and speed similar to those of the use for which the oil is intended.

15 Referring to the work of Ordway and Woodbury in 1884 with an apparatus constructed to apply pressures of 40 lb. per sq. in.; to those of Tower carried on under what he terms great pressures—100 to 600 lb. per sq. in.— in an oil-bath system of lubrication; and also referring to the opinions of others on these results, Redwood presents the view that the agreement between machines and actual practice is extremely slight, his final conclusion being that viscosity affords the most valuable tests of lubricating qualities at our disposal. Inasmuch as Redwood's opinion on machine testing is a result of his observations

during several months on the Ingram and Stafer machines, in which the speed is 1500 r.p.m., and that the friction is gaged by the number of revolutions necessary to carry the temperature to 300 deg. fahr.: it is not difficult to understand his conviction that in his experience testing machines do not afford results comparable with those of actual practice.

16 The value of viscosity as a distinguishing property of lubricating oil is recognized by all who have given attention to the subject, but all are not agreed as to the extent of its practical reliability. Archbutt suggests that the quality of oiliness or greasiness is nearly of as much importance as viscosity. Although, as mentioned above, there is no precise method whereby oiliness can be determined, it is not difficult to recognize it nor to distinguish the marked differences in this respect shown by different oils and greases. Archbutt calls attention to the fact that at very low speeds the friction of a cylindrical journal should be proportional to the viscosity of the oil; but at higher speeds, and consequently increased temperatures, the relation of friction to speed ceases; the viscosity is diminished with a corresponding change in the carrying power of the journal. While fully appreciating the value of the information to be obtained by chemical analysis, Archbutt insists that the oiliness of a lubricant is of especial importance under heavy loads and high speeds. He suggests that it is advantageous for an engineer to test oils for himself on a machine without depending altogether on analytical data of physical tests obtained from the expert. Hurst also mentions that a broader knowledge of the practical working of oils is necessary than can be obtained from chemical or physical tests alone. He maintains that the test of an oil from a journal under the practical conditions of its use show conclusively its adaptability to such use.

17 The principal points to be observed in mechanical tests are the effects of speed, load, temperature, and the frictional effects due to viscosity and oiliness. The measurements on which depend the quality of the oil include the frictional resistance, the temperatures, and the endurance of the oil film. Doubtless the numerous machines that have been constructed for testing oils have certain merits and advantages. In the wide range of work carried on in this field during the past year, a part of the results of which are presented in this paper, the machine devised by Professor Carpenter was used. In its sensitive adjustment, durable efficiency, and the wide range of possible tests, this machine in continuous use during this period on light and heavy oils, greases and graphite, has fulfilled all requirements. Since

the results to be presented are closely dependent upon the method employed a view of this machine is here introduced.

18 This machine has an accurate adjustment for recording the speed, and a long lever arm with a vernier attachment graduated to tenths of a pound for recording the friction. The load is applied by a powerful spring worked by a cam and lever, the limit of the machine being 6000 lb., total load. Careful calibration of the spring showed it to be properly adjusted.

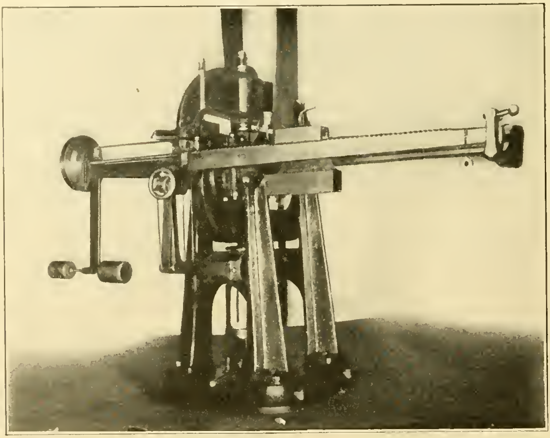


FIG 1 THE CARPENTER MACHINE FOR TESTING LUBRICANTS

19 In projected area the bearing in use is approximately 8 sq. in.; the journal is about 3 in. in circumference, nearly equal to 1 ft. in linear extension. A cast-iron frame babbitted and machined down to a true surface was used for the most part in this work. Even after careful machining some continuous frictional work was necessary on the babbitt surface to bring it to the proper conditions of constant results. The hard form of babbitt mentioned above gave satisfactory results, and there was little difficulty in keeping the surfaces in suitable condition after they were once obtained. For measuring temperatures a thermometer was inserted in a hole in the bearing, extending close to the journal.

20 Tests made at steam temperature—210 deg. fahr.—were carried on in a hollow cast-iron babbitted bearing, with steam attachments by which it was found that the desired temperature could readily be maintained. The lubricant is run in from a sight-feed cup through a small hole close to one side of the bearing with careful regulation of the flow for proper adjustment of the oil feed.

21 For delivery of the lubricant over the entire face of the bearing two channels or grooves are run diagonally across the babbitt face from the inlet hole, giving equal and even distribution; these channels must be carefully gaged for an even flow, otherwise dry spots or streaks appear on the journal accompanied by a sudden greatly increased friction indicated on the friction bar. This detail of operation requires careful and constant attention, for on it depends the continuous regularity of the friction curve. In this respect this method of observation is extremely sensitive, and is one of the important elements in frictional tests. Partial exposure of the journal enables the operator to observe the formation of the film, its comparative thickness and any irregularity due to an imperfect condition of the journal or bearing, or improper lubrication.

22 Accurate testing of the mechanical efficiency of oils with the precise quantitative observations possible on the Carpenter machine, including the various classes of lubricants under consideration in this paper, presented an extensive field of labor, especially since there are no general standards of comparison under any conditions of operation. Such constants must of necessity be based on arbitrary data, nevertheless if they are accurately determined on a standard machine, with the conditions of the journal and bearing selected,—the load and speed,—the constants on this machine may be readily ascertained on any other equally efficient machine. In duplicate tests made with the same bearing and under the same conditions the results were closely concordant. At the outset it should be clearly understood that these tests must be performed with a scientific accuracy of exact quantitative observations with close supervision of all details. The work then becomes the regular routine of any scientific investigation which involves long series of observations, after it is ascertained by preliminary trial what conditions are necessary in testing any given oil. Of course for commercial benefit these conditions should be as close as is practicable to the factory conditions of use.

23 The results to be described of the use of water, kerosene, and fuel oil as vehicles of graphite, present novel and interesting features. Under certain conditions, as mentioned above in steam cylinders, it is

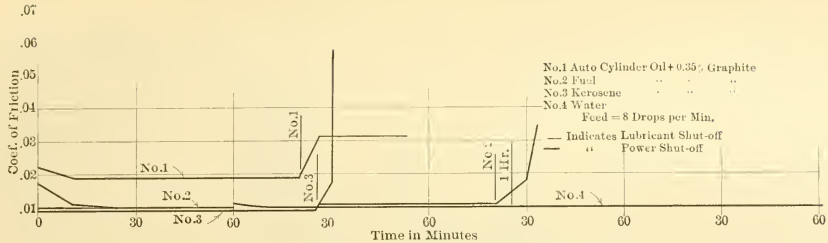


FIG. 2 CURVES OF FRICTION WITH VARYING VISCOSITY OF LUBRICANT. PRESSURE 70 LB. PER SQ. IN.; R. P. M. 446. NO. 1 AUTOMOBILE CYLINDER OIL + 0.35 PER CENT GRAPHITE; NO. 2 FUEL; NO. 3 KEROSENE; NO. 4 WATER. FEED = 8 DROPS PER MINUTE.

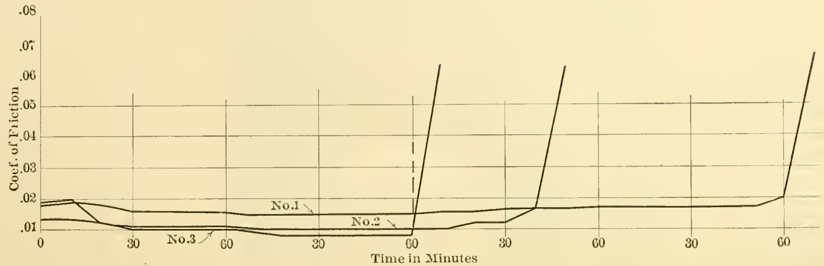


FIG. 3 CURVES OF FRICTION WITH VARYING VISCOSITY OF LUBRICANT. PRESSURE 150 LB. PER SQ. IN.; R. P. M. 445. NO. 1 FAILS SPINDLE OIL + 0.35 PER CENT GRAPHITE; NO. 2 FUEL; NO. 3 KEROSENE. FEED = 8 DROPS PER MINUTE. DOTTED LINE INDICATES LUBRICANT SHUT OFF.

well known to engineers that water alone serves as a lubricating film. But since on journals it serves no purpose whatever, the lubricating qualities of aqueous suspended graphite must be due wholly to the graphite. The same is true of kerosene, which alone is practically devoid of lubricating quality, and likewise of fuel oils.

24 For the purpose of testing the effect of varying viscosity in lubricants, and at the same time the lubricating quality of deflocculated graphite, tests were made with water, kerosene oil, a fuel oil, and an automobile cylinder oil, each carrying 0.35 per cent graphite. The results obtained in these tests are shown by the curves in Fig. 2, in which the speed is maintained at 446, and the load at 70 lb. per sq. in. The observations of frictional load and temperature were made at intervals of ten minutes and on that basis a curve is drawn for each of the lubricants tested; on the chart the time is given in half-hour limits and the coefficient of friction in hundredths of a unit. It will be observed that the curve for water and graphite is practically a straight line, with scarcely any variation for the four hours shown on the curve; this test continued for 15 hours altogether with a precisely similar result. There were several stops which are indicated by a dotted line on the chart, and it appears that there was no change whatever in the direction of the curve by stopping and starting. Curve 3, representing the observations on the coefficient for kerosene oil with graphite, is also a straight line showing a coefficient very slightly lower than water. The coefficient curve for the fuel oil and graphite is also practically a straight line, and with an endurance test extending 1½ hours after the oil supply was shut off; here the frictional coefficient is slightly higher than that of either water or kerosene. A similar regularity appears in the curve of the automobile cylinder oil with graphite; but it is to be noted that the frictional coefficient is very materially higher than those of the other lubricant shown on the chart, which may be considered as a measure of the comparatively greater internal viscosity of the automobile oil; this oil shows a much longer endurance test than appears on this chart.

25 The effect of varying viscosity in lubricants, and the lubricating quality of the graphite under practically the same speed, 445 r.p.m., but with a load of 150 lb. per sq. in.; using kerosene, a fuel oil and a spindle oil, with the same proportion of graphite, and the same oil supply, are shown on Fig. 3. Kerosene here shows a very slight irregularity in its coefficient, which differs only slightly from that on the preceding chart. Here again the greater internal viscosity of fuel oil is shown by the increased friction which appears in this curve. No

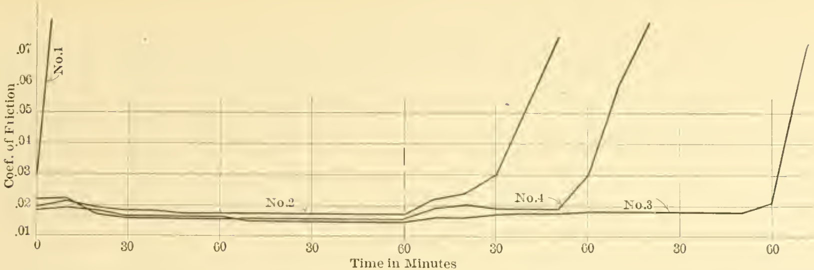


FIG. 4 CURVES OF FRICTION—OIL AND OILDAG—VARYING FEEDS. PRESSURE 150 LB. PER. SQ. IN.; R. P. M. 445. FAILS SPINDLE OIL.

No. 1	Oil alone	6 Drops per Minute	No. 3	0.35 per cent graphite	8 Drops per Minute
No. 2	" "	8 " " "	No. 4	" " "	4 " " "

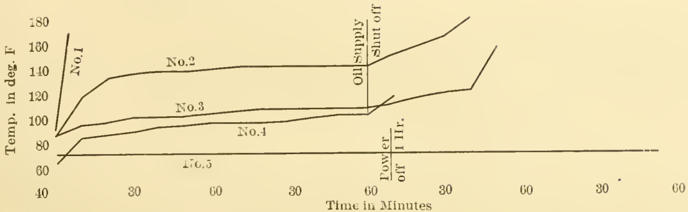


FIG. 5 TEMPERATURE CURVES FOR LUBRICANTS OF VARYING VISCOSITY, WITH AND WITHOUT GRAPHITE. PRESSURE 150 LB. PER SQ. IN.; R.P.M. 444

No. 1	Auto cylinder oil (alone)	6 Drops per Minute	No. 3	Fuel oil + 0.35 per graphite	8 Drops per Minute
No. 2	" " " + 0.35 per cent graphite	4 " " "	No. 4	Kerosene " " " "	8 " " "
			No. 5	Water " " " "	8 " " "

doubt the fuel oil possesses the quality of oiliness in a very slight degree, enabling it in the beginning of the test to take a lower coefficient than kerosene, which maintains a considerably higher coefficient for a few minutes, until the continuous film of graphite has formed and reduced the coefficient to its normal condition. It is evident that the fuel oil also possesses a certain oiliness which enables it to begin the test with a coefficient that changes only slightly during the entire period, including also an endurance test extending through two hours before the oil breaks and with only a slightly increased coefficient of friction after the oil supply was shut off. Another feature worthy of note is the comparative endurance of the three oils. While kerosene, under a bearing load of 150 lb. per sq. in., maintains an extremely low coefficient, the fact that it breaks immediately when the oil supply is shut off indicates that it has not the power to form a coherent graphite film, a power which is possessed to some extent by the fuel oil and in a marked degree by the spindle oil.

26 Fig. 4, load 150 lb. per sq. in., 445 r.p.m., gives the effect on a spindle oil of a variable feed. In one test on the oil alone the oil supply was regulated with the object of breaking the oil at the beginning of the test, and also its behavior was noted, under an oil supply that enabled it to perform its functions as a lubricant. The effect of graphite on the lubricating quality of the oil is also shown in Curve 3 and Curve 4, Curve 3 representing a feed of 8 drops per min., Curve 4 representing a feed of 4 drops per min. The diminished coefficient in Curve 4, as compared with Curve 2, represents the lubricating effect of graphite, and this effect is still further shown by the increased endurance test in Curve 4; it will also be observed that besides showing diminished friction, Curve 4 is based on an oil supply due to the graphite, one-half that of Curve 2 of the oil alone.

27 In Fig. 5 curves are shown which represent the temperatures recorded in tests of friction presented on Fig. 2 and Fig. 3. As in the previous charts the load is given as 150 lb. per sq. in. for the automobile oil, fuel oil and kerosene, and 70 lb. per sq. in. for water. The speed was 444 r.p.m. in all but the test with water, where it was 446 r.p.m. The test of the automobile oil alone showed an immediate rise in temperature, corresponding to the breaking point of the oil, which is shown in the friction test. It is interesting to compare this temperature with that of Curve 2, automobile oil and 0.35 per cent graphite, in which the temperature rises within twenty minutes to a definite point and then continues in a nearly straight line with little variation to the point where the oil supply was shut off at the end of two hours.

Curve 3, representing the temperatures of fuel oil and graphite, also shows a very slight variation after 30 min., when the stable conditions of lubrication were established. A difference in temperatures of approximately 25 deg. is shown between the curves of the automobile and fuel oils, which must represent the larger escape of energy in the form of heat from the bearing, due to the greater internal resistance of the automobile oil. The temperatures of kerosene with graphite, as shown in Curve 4, are approximately 10 deg. lower than those in the fuel oil curve, due to the still smaller internal resistance of kerosene. Bearing in mind the small difference between the specific gravity of the fuel oil, approximately 35 deg. Beaumé, and that of kerosene, approximately 45 deg. Beaumé, the difference in temperatures of these two curves is a good example of the accuracy in observation possible in these tests. Perhaps the most striking feature on this chart is the curve presenting the temperatures for water and graphite; here, as in the curve of friction for water, this curve is shown for only four hours, but the test actually extended through a period of 15 hours, during which time there were several stops in which, as shown on this chart, the temperature at the start was the same as that at the time of interruption. It will be observed that this chart shows an extremely low temperature, 65 deg., practically the same as the room temperature, which it never exceeded by more than 5 deg., and that it is essentially a straight line from start to finish. In this use of water as a vehicle for the graphite there is nothing to interfere with the best work that the graphite is capable of performing.

28 Among the various classes of lubricating oil examined in this work considerable attention has been given to the behavior of heavy engine and cylinder oils, both straight hydrocarbon oils and compounded oils. A special form of bearing was constructed, consisting of a cast-iron frame with a hollow chamber for introducing steam, and a babbitted face using the exceptionally hard babbitt previously described. In some of these tests a bronze bearing similarly constructed, but maintaining the bronze face, was employed. But in general it was observed that the results were less satisfactory with the bronze than with the babbitt bearings, in testing not only the heavy oils but the other classes of oils examined. Hard babbitt seems to possess certain peculiar qualities adapted to the various details and variations in speeds, loads, and temperatures, which are not found in the same degree in the bronze alloys. To show the results obtained in testing cylinder oils, charts are here presented on three commercial products, the American cylinder oil, Galena cylinder oil, and "600 W" cylinder

oil. Tests were also made on the influence of graphite on these oils, with reference to the frictional coefficient and endurance of the oils. The physical constants of the oils are also given for comparison, especially of specific gravity and viscosity. The general procedure of the tests included a continuous run for two hours at which time the supply of oil was shut off.

29 In Fig. 6 of the American cylinder oil, which is a straight hydrocarbon oil, the data of the tests include the use of the bronze bearing, a supply of lubricant at the rate of four drops per minute, a total pressure of 1200 lb., and a speed of 245 r.p.m. The curve of the straight oil begins at a somewhat higher coefficient that is maintained

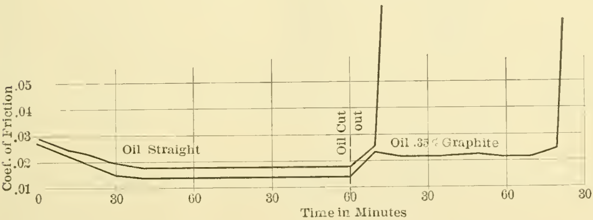


Fig. 6 American Cylinder Oil, with and without Graphite. Bzonze Bearing; 4 Drops per Minute; 1200 lb. Pressure; Temperature 210 deg. Fahr.; Viscosity 100 deg. at 212 deg. Fahr.; Flash 440 deg. Fahr.; Specific Gravity 0.961.

after the first half-hour, when normal conditions are established, and it then proceeds in a straight line with no variation to the point where the feed is stopped. The endurance run of this oil is doubtless considerably shorter than it would have been with the use of babbitt bearings; in fact this was demonstrated in another test in which babbitt was used. With graphite the oil follows closely the direction of the other curve but with a very considerable diminution in the coefficient of friction. It further appears in the endurance test that the graphite carries the load with slightly increased friction for a period of 1 hr. 20 min., which would doubtless have been considerably prolonged if babbitt had been used.

30 Fig. 7 presents results obtained in tests of the "600 W" cylinder oil, with and without graphite. A comparison of physical constants with those in Fig. 6 shows a materially lower specific gravity and somewhat higher viscosity. In these tests the same total

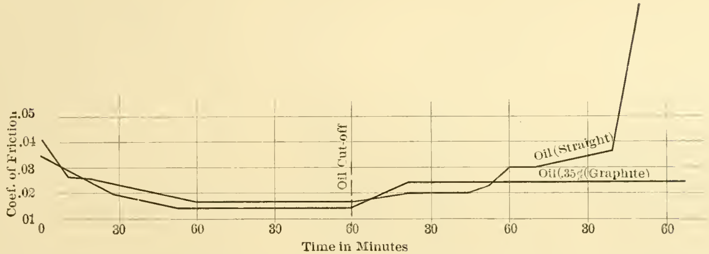


FIG. 7 "600 W" CYLINDER OIL, WITH AND WITHOUT GRAPHITE. BABBITT BEARING; 8 DROPS PER MINUTE; 1200 LB. PRESSURE; TEMPERATURE 210 DEG. FAHR.; VISCOSITY 150 AT 212 DEG. FAHR.: SPECIFIC GRAVITY 0.903; FLASH 530 DEG. FAHR.

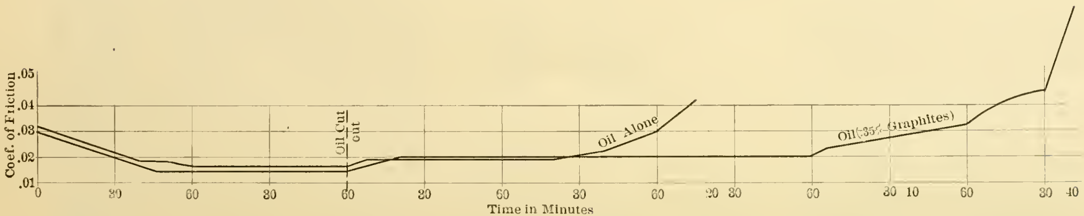


FIG. 8 GALENA CYLINDER OIL WITH AND WITHOUT GRAPHITE. BABBITT BEARING; 8 DROPS PER MINUTE; 1200 LB. PRESSURE; TEMPERATURE 210 DEG. FAHR.; VISCOSITY 116 AT 212 DEG. FAHR.; SPECIFIC GRAVITY 0.947; FLASH 266 C.

pressure, 1200 lb., and the same speed, 245 r.p.m., were used, but the oil feed was double that in the preceding tests and the babbitt bearing was employed. On account of the greater viscosity the straight oil showed at the beginning a considerably higher coefficient and the tests continued one hour before the oil had reached normal conditions, which it maintained until the feed was stopped and doubtless would have continued indefinitely. After the oil was shut off lubrication was maintained with some slight irregularity and increased friction during 1 hr. 40 min., the point at which it broke. Similar conditions are observed in the curve which expressed the variation in the coefficient of friction of this oil with 0.35 per cent graphite; it begins the test with a somewhat lower friction, reaching normal conditions sooner than the straight oil, continues in a straight line to the point where the supply is stopped, and then still continues in a straight line with somewhat increased friction. The endurance curve would doubtless have continued for a considerably longer time but the power was shut off at the point where the curve terminates. A marked influence of graphite on the behavior of this oil is plainly apparent in a comparison of these curves.

31 In applying tests to the Galena cylinder oil, with and without graphite, the same feed, load and pressure were used as with the preceding oil and the tests were made on a babbitt bearing. In viscosity this oil is somewhat less than the preceding oil, the specific gravity somewhat higher. Both curves in Fig. 8 begin with slightly lower coefficient at 0.03, and this difference is maintained until the oil is shut off and for $1\frac{1}{2}$ hours on the endurance test. To reach normal conditions the straight oil ran for 1 hr., the oil with graphite 45 min. After the feed was stopped, the curves proceed regularly with slightly increased friction, the oil alone practically breaking in $1\frac{1}{2}$ hours, the oil with graphite proceeding with perfect regularity for three hours, changing slightly during the next hour and breaking at the end of $4\frac{1}{2}$ hr. The tests represented in Figs. 6, 7 and 8 are not intended to present the comparative efficiency of these particular oils but to demonstrate the application of this method of testing and also to compare the effects of deflocculated graphite.

32 The results presented in this paper, with reference to the uses of graphite as a solid lubricant, indicate that in the deflocculated form it can readily be applied with great economic efficiency in all forms of mechanical work. One of its most characteristic effects is that of a surface-evener, by forming a veneer, equalizing the metallic depressions and projections on the surfaces of journal and bearing; and being

endowed with a certain freedom of motion under pressure, it affords the most perfect lubrication. In automobile lubrication the great efficiency of graphite, in increasing engine power, in controlling temperatures, and in decreasing wear and tear on bearings, has been brought out in a series of tests conducted by the Automobile Club of America. In connection with the reduction in friction of lubricating oils by graphite the extremely small proportion necessary is worthy of note; the proportion used in this work is equivalent to one cubic inch of graphite in three gallons of oil. The curve of temperature for Aquadag, an increase but slightly above that of the surrounding atmosphere, demonstrates an important economic quality of controlling temperatures in factory lubrication, thereby avoiding the danger of highly heated bearings, which are frequently the cause of fires.

33 In the observations described in this paper, and in fact in all the work that has been done in this field, thère is not a more impressive example of the efficiency of graphite in lubrication than that presented in the curves of friction and temperature of water and graphite; for water serving merely as a vehicle and completely devoid of lubricating quality, the graphite is permitted to perform its work without aid and with no limiting conditions.

DISCUSSION

TAN BARK AS A BOILER FUEL

By David Moffat Myers, Published in The Journal for October

ABSTRACT OF PAPER

The average fuel value of spent hemlock tan is about 9500 B.t.u. per lb. of dry matter, which is about 35 per cent of its total moist weight in the fireroom. The available heat value per pound as fired is 2665 B.t.u. One ton of air-dry hemlock bark produces boiler fuel equal to 0.42 tons of 13,500 B.t.u. coal. The degree of leaching does not affect the number of heat units per pound of dry matter, but of course reduces the available material.

Boiler tests under normal conditions show thermal efficiencies of from 58 to 68 per cent, and a higher efficiency has been obtained under special conditions.

Tan presses have produced no marked increase in boiler and furnace efficiency when tested; with the same efficiency, however, an increase of about 5 per cent of steam for the same amount of tan bark may be expected owing to the increase of available heat units in the "tan as fired." Grate surfaces should be materially reduced when tan is pressed.

Mixing coal with tan under proper conditions increases both the capacity and the efficiency of boiler and furnace.

Conditions productive of best results have been: ample combustion space, and a refractory arch over the entire grate; no less than 0.5 in. and preferably of 0.6 in. water-gage draft with ample draft passages; feeding through holes in top of furnace in small quantities and at frequent intervals to approximate the rate of combustion; constant care to prevent blow-holes; a small shallow-fired furnace; a high arch above the fire (which is about the most important single requirement); proper ratio of heating surface to grate surface for local conditions; the pressing of tan under certain conditions.

ADDITION TO PAPER BY AUTHOR

The following illustrations and descriptive matter have been added by the author and should therefore be considered a part of the paper as presented at the December meeting.—Editor.

73 The following illustrations, reproduced from working drawings and sketches, will give some idea of the construction of furnaces for burning spent tan bark, sawdust, and bagasse.

74 Fig. 2 is a working drawing of the self-feeding tan-burning furnace designed by the writer and referred to in Par. 12 and Table 4.

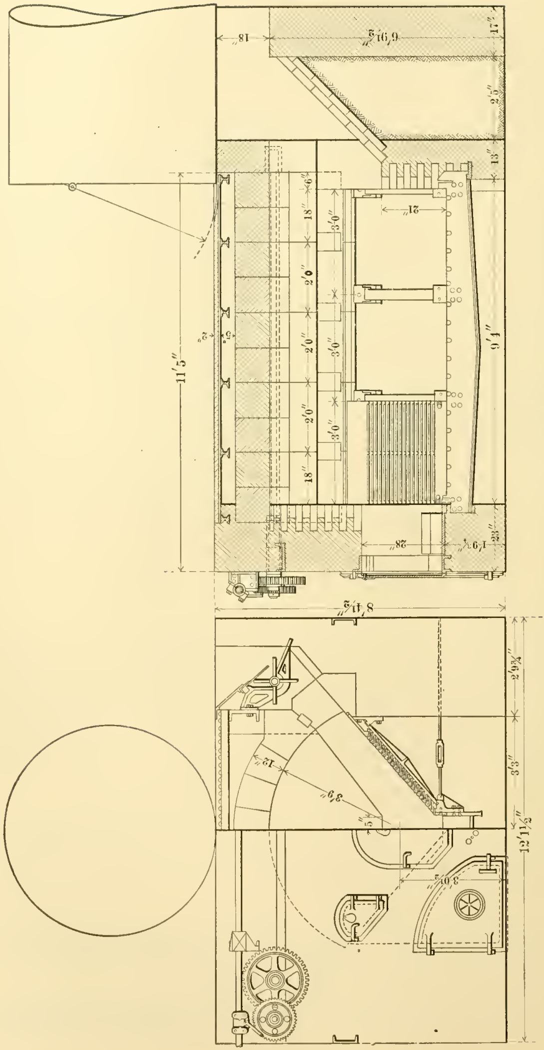


Fig. 2 End and Side Sectional Elevation[1] of the Myers Tan-Bark Furnace

75 Fig. 3 shows the construction of the grate bars, which provide the horizontal draft opening tending to produce the draft action referred to in Par. 13.

76 Fig. 4 shows the application of these grates to bagasse burning. The stokers are done away with in this case, the fuel being fed by gravity to the feed chutes with weighted flaps which are used all over the islands of Cuba and Porto Rico. This burner has not yet been applied to bagasse burning.

77 Fig. 5 and Fig. 6 show the types of tan furnaces found by the writer in common use throughout the country. Fig. 5 shows what was known as the old Hoyt furnace. It was originally designed when tan bark was so plentiful that it was necessary to burn it. The writer has found these furnaces with inside lengths as great as 24 ft. on the grate surface. Fig. 6 shows a more modern type of burner designed to give a more even distribution of the fuel on the grates.

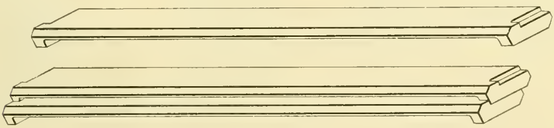


FIG. 3 DETAIL OF THE GRATE BARS OF THE MYERS FURNACE

78 Fig. 7 shows a more up-to-date furnace designed for the hand firing of a mixture of coal and tan, the coal being mixed with the tan before entering the furnace, which is supplied with shaking or shaking and dumping grates. When coal is mixed with tan in any considerable proportion, more air is required for combustion, the best air spacing in the grate bar being found to be $\frac{3}{8}$ in. The percentage of draft area for this purpose should be about 40 to 50 per cent, depending upon how large a percentage of coal is used with the tan.

79 Fig. 8 shows what is known as a hump-back grate, which has been installed in different tanneries for the purpose of increasing the consumption of fuel in a given furnace. For instance, in a plant that had trouble in consuming all its tan bark, the writer merely took out the grate bars and put in a ridge bar as shown and converted the grate surface into the hump-back form. The result was that the consumption of tan bark per furnace was increased from 12 tons per day on the dry bark basis to 15 tons.

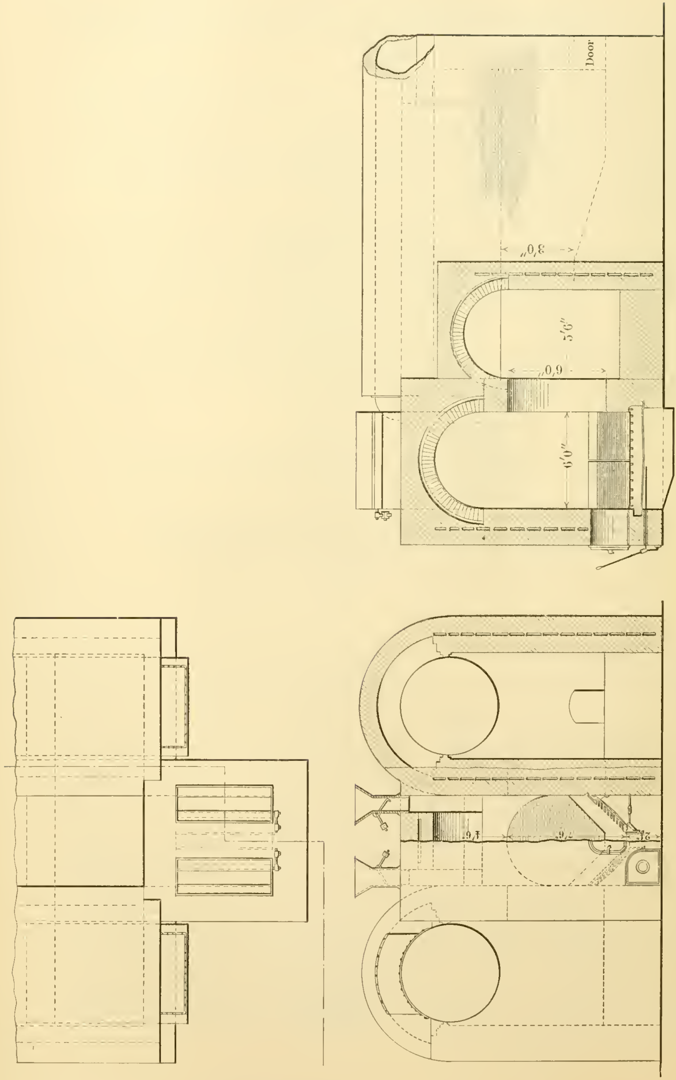


Fig. 4 Partial Plan, Side and End Elevations of the Myers Furnace for Burning Bagasse

80 Fig. 12 shows what was known as the Thompson type of tan furnace. The MacMurray furnace, with a convex grate surface and feed pipes, is a type quite a number of which the writer has seen in operation.

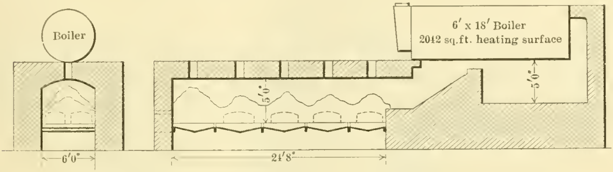


FIG. 5 THE EARLY HOYT FURNACE FOR BURNING TAN BARK

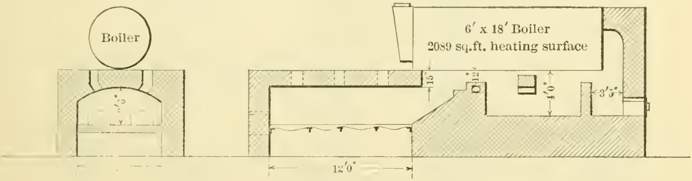


FIG. 6 A TAN FURNACE WITH SIX FEED HOLES

THE SETTING HAD AIR ADMISSION IN THE BRIDGE WALL AND A BAFFLE ARCH IN THE COMBUSTION CHAMBER. VERY GOOD RESULTS WERE OBTAINED.

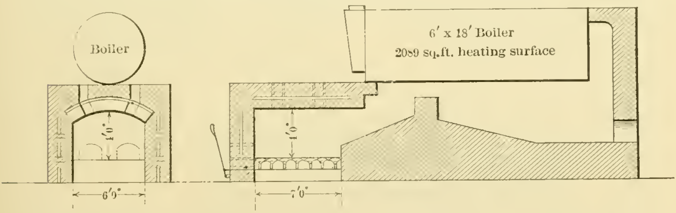


FIG. 7 A FURNACE WITH SHAKING GRATES FOR BURNING A COAL AND TAN MIXTURE

AIR SPACES OVER FIRE ARCH AND IN WALLS OF FURNACE AND BOILER WALLS. DISTANCE FROM GRATE TO TOP OF ARCH INSIDE SHOULD NOT BE LESS THAN 4 FT.

81 Fig. 10 is another form of tan furnace which gave good results in a plant in the South. The hump-back form of grate is reversed something like that used in the writer's stoker furnace, except that the tan is fed through a number of feed holes along the upper edges of these grates. This furnace was designed by the foreman in a Southern tannery.

82 Fig. 11 shows a design of the writer's for an adjustable gravity-feed furnace for burning tan or sawdust. The feed chutes are rectangular in section and contain adjustable chutes to regulate the depth of tan on the grates for any condition of draft, etc.

DISCUSSION

Albert A. Cary. The furnace described by Mr. Myers consists of an extension in front of the regular boiler setting, with a number of circular stoke holes, or openings through the top arch, over the

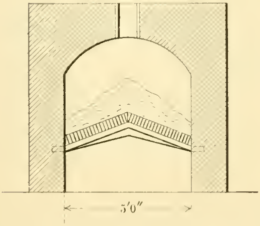


Fig. 8 Cross Section of Furnace with Hump-Back Grates and Bearing Bar

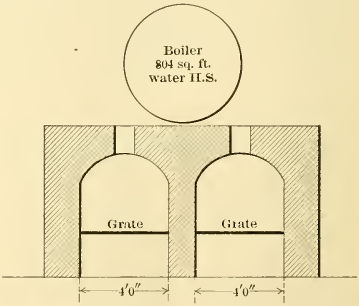


Fig. 9 Cross Section of a Double-Arch Tan Furnace of the Thompson Type on which a Test was Run

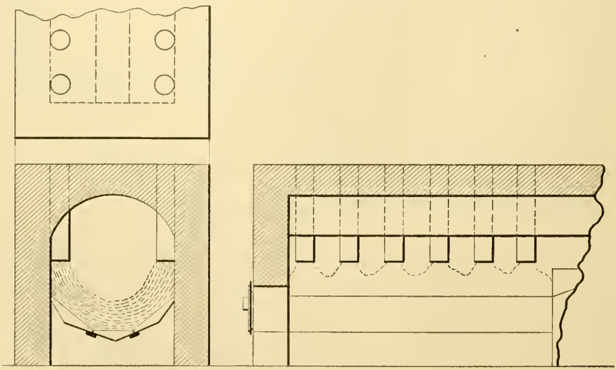
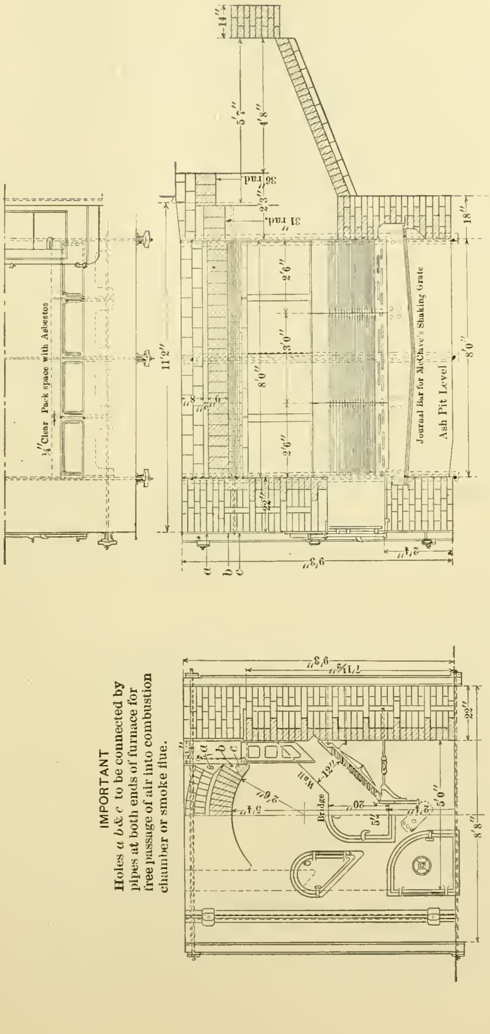


Fig. 10 Bush Tan Furnace with Multi-Tube Feed.



LONGITUDINAL SECTIONAL ELEVATION

FRONT ELEVATION

FIG. 11 A MYERS FURNACE WITH ADJUSTABLE GRAVITY FEED. ADAPTED FOR BURNING TAN BARK OR SAWDUST

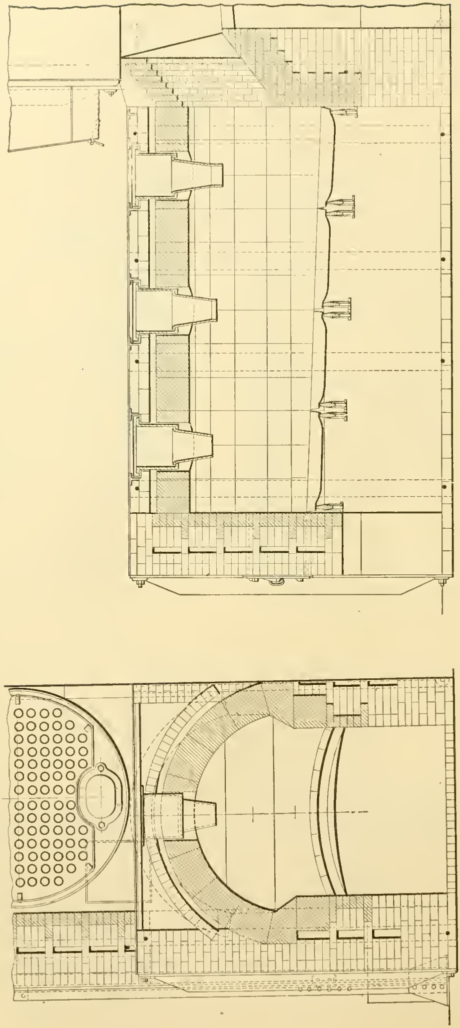


Fig. 1 The McMurray Furnace for Burning Spent Tan Bark.

grate. No little trouble has been experienced with this construction, due to the destruction of the lower end of these circular fire-brick tubes through which the fuel is charged to the furnace.

2 If these stoke holes could be always completely filled with fuel, so as to prevent inrushes of air, this destructive effect could be materially checked. However, as the method of charging fuel by hand is an intermittent one, the upper end of the cone of spent tan bark, soon after charging, drops below the level of the top of the arch, the inrushing air meets the hot furnace gases at these points and intense combustion results. For this reason, and due to the fact that when the excessive moisture in the fuel rises as a vapor against the arch, rapidly abstracting its heat (to become superheated steam), the fire brick cracks and disintegrates, finally resulting in a chipping off of the brick-work of the reverberatory arch around the lower end of the stoke holes. Repairs are therefore frequently necessary.

3 A continuous automatic feeding device, which would keep these stoke-holes constantly filled with the moist fuel, would undoubtedly do much to relieve this trouble by preventing an excessive infiltration of air at frequent intervals of time. Mr. K. McMurray of New York, has devised a very ingenous method for overcoming this trouble in hand-stoked furnaces. Fig. 1 shows both front and side sectional elevations of this furnace.

4 In the stoke hole is fitted a circular lining of cast iron which does not extend to the level of the inside of the arch. The lining is finished with a shoulder which diminishes the diameter of the opening by about two inches. A tube or open thimble drops into this frame, being held by a rim cast around its upper end. The lower end of the thimble extends about a foot into the furnace.

5 The fuel charged into the stoke hole falls through the thimble, and forms a cone-shaped pile below it on the grates. When the stoke hole becomes uncovered, the in-rushing air causes the intense combustion to take place, not on a level with the brick-work, but at a level below the thimble, and the life of the fire-brick arch at the stoke-hole openings is thus greatly prolonged. The ends of the cast-iron thimbles burn off gradually, but they cost but little, and are easily pulled out and new ones are inserted in their place.

6 Another trouble met with in this type of furnace is the rapid burning away of the fuel next to the side walls and the consequent large infiltration of air from the ash pit. This trouble has been largely overcome by reducing the width of the furnace by about 1 foot at the grate level, as shown in the front sectional elevation. The ledges

formed on either side of the lower part of the furnace support the cone of charged fuel on each side, thus keeping the grate effectually covered with fuel.

7 In this construction it will also be seen that instead of using a flat grate, the grate bars are curved so that the grate surface is higher at the center of the furnace than at the sides. This design decreases the thickness of the fuel bed under the stoke holes and causes a thickening of the fuel bed at the sides of the furnace.

8 Since water can be evaporated in the furnace itself only at a great loss, every practicable facility should be utilized for depriving the wet fuel of its moisture. Mr. Myers has mentioned the comparatively small gain from pressing the moisture out of the spent tan. I have used special rolls for extracting the water from moist fuels, with a desirable gain resulting. These rolls are of cast iron and run in pairs, one roll being about 12 in. in diameter, the other about 14 in. and both held together by heavy springs. As both rolls are revolved at the same number of revolutions per minute their surface speeds are necessarily different. The faces of the rolls are roughened by having a shallow checker work pattern cast upon them. The fuel is fed to the rolls continuously, and due to the tearing or macerating action between the rolls faces more than double the amount of water is thus worked out, as compared with the press results given in Mr. Myers' paper.

9 In one case, where the chimney was located some distance from the boilers, a wrought-iron rectangular flue was used to connect them, a shallow iron trough being formed on the surface of the flue by having the edges on the two vertical sides continued above the level of the top. The other three sides of the flue were covered in the usual way. The moist fuel was fed upon the chimney end of the flue and was drawn by a conveyor towards the boiler and over its top, whence it was delivered on top of the extension furnace. A small evaporation of moisture took place, sufficient to make this device desirable. The heat from the top of the boiler and the extension furnace may also be used in this way. The waste heat from the boiler may also be used to pre-heat the air delivered to the ash pit. I know of no condition where pre-heated air can be used to better advantage than with moist fuels.

10 Mr. Myers has spoken of the advantage of the high furnace over the low furnace. My experience thoroughly endorses this. When the moist fuel is charged into the hot furnace, a cloud of steam is evolved, which, when crowded down upon the burning fuel in

a low furnace, hinders combustion. A sufficient amount of steam would eventually extinguish the fire.

11 In addition to the effect of moisture described in Par. 7 and Par. 8, the large space occupied by the steam in the combustion chamber interferes with the combination of oxygen and the combustible gases evolved from the fuel.

12 In the flue-gas analysis obtained with moist fuels, of course the water in the gases condenses and is not accounted for in the analysis given.

William Kent. I consider this the most important paper on the subject of tan bark as a boiler fuel which has appeared in over thirty years. The only other paper that I know of is one by Prof. Thurston published in 1874 in the Journal of the Franklin Institute. He made some boiler tests on tan bark for fuel, using two different styles of furnace, some of his results being better than those given by Mr. Myers. I think that still better results are yet to be obtained from the use of tan bark as a fuel, by compressing out as much as possible of the moisture and using the waste heat of gases to dry the bark before it is put in the furnace. For burning the bark we must have a large fire-brick combustion chamber and give plenty of time to the burning of the gases, and then we will get as near the theoretically possible economy as can be expected.

2 The principal cause of poor economy in the burning of tan bark, besides the difficulty of securing good combustion in the furnace, is the amount of heat that is carried away in the shape of superheated steam in the chimney gases. If the bark, after being partly dried by compression, were further dried in a rotary drier by the waste heat from the chimney gases, there would be a very important gain in economy.

3 I have made a calculation showing the theoretical results that may be obtained in burning tan bark of different degrees of moisture under certain assumed conditions, the results of which are given herewith: The dry bark is assumed to have the following composition $C = 0.50$; $H = 0.06$; $O = 0.40$; N and ash = 0.04. Substituting in Dulong's formula, $14{,}600\ C + 62{,}000 \left(H - \frac{O}{8}\right)$, its heating value is 7920 B.t.u per lb. Bark containing 20 per cent moisture would have a heating value of $0.80 \times 7920 = 6336$ B.t.u.

4 Assuming the chimney gases to escape at 600 deg., the heat required to evaporate the water from 62 deg. and to superheat the

steam to 600 would be (212-62) + 970 + 0.48 (600-212) = 1306, or for 20 per cent moisture, 261 B.t.u. per pound of tan.

5 The 0.06 lb. of H in a pound of dry tan will unite with 0.06 × 8 = 0.48 O, making 0.54 lb. H_2O, which escapes as superheated steam carrying away 0.54 × 1306 = 705 B.t.u. for each pound of dry tan or 0.80 × 705 = 564 B.tu. for tan with 20 per cent moisture.

6 Assuming 25 lb. of air to be required per pound of C + H in the fuel or 25 × 0.56 = 14 lb. of dry tan, the heat carried away by this air heated to 600 deg. is 0.24 × 14 × (600-62) = 1808 B.t.u. per pound of dry tan or 1446 B.t.u. for tan with 20 per cent moisture. Using the figures thus found the following table is constructed:

Moisture	B.t.u. per lb. wet tan	Losses of heat due to Moisture	H in fuel	Heating air	Sum of losses	Net heat value B.t.u.	Efficiency per cent	Lb. Evap. per lb. wet tan
0.20	6336	261	564	1446	2271	4065	64.2	4.19
0.30	5544	392	493	1266	2151	3393	61.2	3.50
0.40	4752	522	423	1085	2030	2772	57.3	2.81
0.50	3960	653	352	904	1909	2051	51.8	2.11
0.60	3168	784	282	723	1789	1379	43.5	1.42
0.70	2376	914	211	542	1667	709	29.8	0.73
0.80	1584	1045	141	362	1548	36	2.5	0.03

7 Suppose that tan with 60 per cent moisture were dried to 20 per cent before being put into the furnace, using for this purpose the waste heat of the chimney gases, we would then have 0.40 dry tan + 0.60 moisture dried to 0.40 dry tan + 0.10 moisture, 0.50 water being removed. Suppose the moisture and the waste gases left the drying chamber at 300 degrees. Each pound of water dried out would take (212 − 62) + 970 + 0.48 (300 − 212) = 1162 B.t.u. and 0.5 lb. would take 581 B.t.u. The H in the 0.40 lb. of dry tan would make 0.216 H_2O, which would take away 0.216 × 1162 = 251 B.t.u. Heating the air would take 0.40 × 14 × 0.24 × (300 − 62) = 320 B.t.u. The sum of these is 1152, which subtracted from 3168, the total heating value of tan with 60 per cent moisture, leaves a net value of 2016 instead of 1379, the figure given in the table. The efficiency would be 2016 ÷ 3168 = 63.6 per cent, instead of 43.5 per cent, and the evaporation from and at 212 deg. 2016 ÷ 970 = 2.08 lb. instead of 1.42 lb.

Prof. F. R. Hutton. In 1874, the late Robert H. Thurston presented a paper on The Efficiency of Furnaces Burning Wet Fuel,

before the American Society of Civil Engineers.[1] At that date few engineers were paying attention to fuel economy, and there was little widespread knowledge as to the details by which it would be obtained. There was of course no formulated code for boiler testing. This paper introduced the writer at that time to the problems of boiler testing, and recorded for the first time for him the formulæ for the barrel type of steam calorimeter.

2 The two furnaces examined were designed to meet the same requirements as are assumed in Mr. Myers' paper; but the press which may be expected to expel a proportion of the water absorbed from the leaching process was not in use, and no data were given as to the proportion between the dry bark ground at the mill and the weight of wet leached fuel delivered at the fire room. The Dutch oven type of furnace was in use, consisting of a fire-brick chamber covered with a reverberatory arched roof. The fuel was fed in at the top of the oven through two holes in the length of the grate. The grate was of fire brick moulded to obtain a semi-cylindrical surface to the upper and lower surface of each bar unit, the concave side being downward towards the ash pit. A large proportion of the finer tan lumps was expected to fall through the holes in the arched bars of the grate and complete their combustion there on the ash-pit floor.

3 But it is very plain from the results of the tests that the furnaces were on very much the same plane of efficiency as those reported by Mr. Myers, since the respective results of evaporation from and at 212 deg. per pound of combustible were for the Crockett furnace 4.41 lb., for the Thompson 5.68 lb. and for the Myers' furnace 5.43, 4.71 and 4.54 lb., if equal accuracy be assumed in the old tests as compared with the new. This is open to doubt, however, as certain figures were assumed or deducted from other experiments and were criticized in the discussion of the results.

4 The present paper is especially interesting to the writer, because it represents the work of a furnace designed by Mr. Myers which seems to incorporate some eminently sound principles. I think all will agree that the three cardinal principles for the complete and smokeless combustion of a reluctant fuel involve the following:

a Time enough for access of oxygen in the air to the carbon gas from the fuel.

b Temperature enough for the rapid and complete chemical union of this oxygen with carbon and hydrogen.

[1]Trans. Amer. Soc. C. E., No. 102, Vol. III, 1874, p 290.

c Room enough for each atom of fuel gas to meet the oxygen atoms with which it is to unite.

The practical attainment of these results is made more difficult when the fuel is wet and in small particles of light weight.

5 We have the conflicting conditions of a hot fire and a slow rate of combustion, to combine with an intensity of draft which shall not be high. Mr. Myers does this by using the step-grate idea, so as to admit the necessary air horizontally between the overlapping bars, whereby the dropping of fine fuel into the ash-pit is prevented: but in addition and as a special excellence of the design, the grate is made to consist of two sections facing each other with their planes parallel to the long axis of the Dutch oven and the shell of the boiler. They are, as it were, upon the inclines of a truncated capital letter V.

6 The bark is fed by a measuring stoker cylinder, which drops a determined volume upon the whole length of the upper bar at each partial revolution, and this fall of new material displaces downward some of what has been drying and growing ready to ignite from the previous charges. At the bottom of the truncated V is a dumping grate from which the residue of ash may be released at intervals.

7 The consequence of the inclination of the two grate sections, with a horizontal inflow of the air, seems to be the same as is produced in a successful form of burner for acetylene gas. The two currents of gas and draft appear to meet in the center or in the axis of the V and an intense combustion takes place there, the heat of which reverberates downward from the arch of the oven, raises the temperature of the upper layers of fuel, and stimulates the rate of the union of combustile with oxygen. Such a furnace of course is not subject to the alternations of the "famine and feast" conditions when excess of wet fuel deadens the fire and causes a smoky and slow combustion, alternating with high heat and good flame and followed in turn with burned-out spots in the fire until fresh charges came in through the holes.

8 The system is also most effective for "bagasse," the wet juicy fibre of the sugar cane after passing through the pressing rolls. This is more difficult to stoke mechanically than the comminuted bark, but the requirements for its successful combustion are very satisfactorily met. Sawdust and scrap from wood-working shops also are burned in furnaces of this design with less danger from sparks at the stack.

9 Referring to the summaries by the author, it should be plain that the geater surface must be reduced if the tan is press-treated

(Par. 56) to remove moisture. Bulk for bulk, there are more heat units per unit of volume or of weight after a volume or weight of water has been expelled than there were when the tan was saturated and not pressed. If the fire is hot enough to dissociate the oxygen and hydrogen which compose the water, the heat for such dissociation is drawn from somewhere: doubtless from the flaming gases, where the process takes place, and of course they are cooled, and perhaps killed.

9 If such oxygen and hydrogen recombine, nothing is lost, and perhaps a mechanic-thermal advantage is reaped because the hydrogen flame is longer than the carbon flame. If for any reason such dissociated hydrogen does not get a chance to recombine from lack of temperature or time or room, there is a loss. Mr. Myers' results should serve to check the claims still advanced at intervals, that the combustion of steam-gas is a source of any great possible economy.

The Author. Mr. Cary in his discussion has described the McMurray tan furnace—one of many different types and designs now in use. All the ordinary forms of tan furnaces feed the fuel through holes in the top or arch over the grate. The number and arrangement of these feed holes vary in the different designs, but they all form a bed of fuel composed of cones of tan. For this reason they are all subject to the objection made by Mr. Cary, i. e., that the fuel burns away most rapidly around the bottom of these cones where the depth of fuel is least. The central parts of the cones offer great resistance to the draft so that active combustion takes place on only a small percentage of the entire grate surface. This necessitates large grate surfaces and large furnaces with attendant radiation losses.

2 Another objection to the cone method of feeding the fuel, especially when only a single row of feed holes is employed, is that the fire is actually divided into a number of small fires around the bottom of the cones. This multiplicity of small fires separated by heaps of wet tan of low temperature results in lowering the furnace temperature and in retarding combustion.

3 In furnaces of this type with careless firing the writer has seen fully one-half of the grate surface doing no work at all in the way of any active combustion. These ill effects are best eliminated by very frequent feeding of the tan in small amounts, so that the percentage of wet tan in the furnace at any time is very small compared to the actively burning mass. High furnace temperature is thus maintained, more grate surface is active and the rate of combustion per square foot is greatly increased. The result is less grate surface required,

smaller radiation loss due to smaller furnaces and greater ease in handling and cleaning the fires.

4 In general the greater the number of feed holes the higher will be the rate of combustion and the smaller the furnace required. Rapid firing in small amounts to equal the rate of combustion in the furnace is productive of best efficiency with any of the usual types of tan furnaces.

5 Tan presses of different makes, but all of the same type described by Mr. Cary, have been experimented with by the writer. It was found that with careful adjustment and attendance the presses would equal the performance quoted by Mr. Cary but that under tannery conditions of indifferent attendance and unskilled labor the presses do not maintain their efficiency.

6 The interference of the steam gas evolved from the fuel with the union of the combustible gases with the oxygen must be overcome by providing large combustion space, preferably over the fuel bed, by special baffles or by special draft action as in the writer's design of automatic furnace shown in Figs. 2 and 3 and referred to by Professor Hutton.

7 The chemical composition of tan is assumed by Professor Kent to be practically the same as that given from an actual analysis in the author's paper. The heating value according to Dulong's formula is 7920 B.t.u. per lb., whereas the results of a large number of tests in a bomb calorimeter by Dr. Sherman, shows the heating value of a pound of dry hemlock tan to be close to an average of 9500 B.t.u.

8 I have carefully read the record of tests on tan burning furnaces made by Prof. R. H. Thurston, and presented in a paper before the Franklin Institute in 1874. Professor Kent states that some of the results there given are higher than those determined in recent practice by the writer. The two evaporative results by Thurston are given as 4.24 lb. equivalent evaporation from and at 212 deg., in the boiler per pound of combustible for the Thompson furnace, and 3.19 lb. for the Crockett furnace. The corresponding figure obtained by the writer in his automatic furnace was 5.55 lb.; that is, over 31 per cent better than Thurston's best result.

9 The writer finds that the evaporations of 5.68 and 4.41 for the Thompson and Crockett furnaces respectively were obtained by Thurston by *adding to the evaporation in the boiler the amount of moisture in the fuel evaporated from and at* 212 *deg.* A similar addition to the writer's evaporation in the boiler of 5.55 lb. would make an evaporation of 7.75 lb. including the moisture in the fuel. The latter

figure is therefore the one to be compared to Thurston's result of 5.68 lb. On the same basis of calculation the economic result of present best practice is over 36 per cent higher than the best result recorded by Thurston.

10 Moreover the highest result in the Thurston test was obtained by a rough volumetric approximation of the weight of the fuel used. It was not weighed to the fireman as in all the author's tests. Furthermore, both the weight and temperature of the feed water were merely approximated and assumed to be correct in the Thompson furnace test; whereas these values in the author's tests were all observed and recorded in a most accurate and systematic manner.

11 The accuracy and reliability of these old tests is very much to be doubted, as Professor Hutton suggests. But even if taken at their full values it is seen that the results of present practice have exceeded the old results by over 30 per cent.

12 Actually the present results are probably even higher than this, from a comparative standpoint, for the reason that in the old days of tanning, the moisture in the tan was less than in present practice. This consideration would have given the Thurston tests a decided advantage in the shape of a greater available heat value of the fuel. Thurston gives the moisture contents of the fuel as fired as 55 and 59 per cent, whereas the moisture in the writer's automatic furnace test was 65.3 per cent.

13 This increase in moisture is due to radical changes in the process of leaching the bark. Where formerly the bark was treated with cold, or nearly cold, water it now is leached at temperatures as near the boiling point as possible, and is subjected to the leaching process two or three times as long as in the former methods. This is on account of the high price of bark nowadays, which makes it pay to leach out as much of the tannin as is practically possible. Some tanneries to-day leach their bark so thoroughly that only $\frac{1}{2}$ per cent to 1 per cent of tannin remains in the spent tan.

14 The author desires to add that all results and data given in his paper are results of actual tests made under working conditions. No assumptions or theoretical calculations are involved in the conclusions. The feed water was in every case measured by means of two tanks or barrels set above a reservoir from which a separate feed pump supplied the boiler. Feed connections were so separated that it was physically impossible to pump the water elsewhere than in the boiler being tested. All connections involving a chance for leakage were blanked off. Valves were never assumed to be tight

but were proved so during the entire test by means of an open-tee arrangement which would show any leakage.

15 The temperature of water entering as well as leaving the measuring barrels was taken at frequent regular intervals. The barrels were calibrated by weighing when filled to their overflow pipes with water at the temperature which the feed water had averaged during the test.

16 The fuel was in every case weighed in equal amounts to the fireman. A sample corresponding to each 200 lb. was taken, kept in closed receptacles and at the end of the test was mixed, and quartered down to a quart or two quart sample which was sent in sealed jars to Dr. Sherman for determination of B. t. u. and moisture. All readings and observations were obtained with like regard for accuracy of results.

17 In Par. 3 Professor Hutton also compares the best results obtained by the writer with those of Professor Thurston; but as before pointed out, the results are on a very different basis and are not comparable, unless the moisture in the fuel is also added to the equivalent evaporation obtained in the boiler. If this is done the following table gives a correct comparison:

POUNDS EQUIVALENT EVAPORATION FROM AND AT 212 DEG.

Including Water In Fuel		Excluding Water in Fuel	
Thurston Tests	*Myers Test*	*Thurston Tests*	*Myers Tests*
5.68 for Thompson furnace	7.75 for Myers furnace	4.24 Thompson furnace	5.55 for Myers furnace
4.41 for Crockett furnace	6.63 for present ordinary furnace	3.19 for Crockett furnace	4.30 for present ordinary furnace

The table shows that when compared on the same basis of efficiency the art of tan burning has been greatly improved over the old methods, both with improved and ordinary furnaces.

18 Thermal efficiency is of course the safest and most accurate basis of comparing results of various boiler and furnace settings, and the highest result yet obtained in a reliable witnessed test in tan burning was 71.1 per cent. This is based on available heat in the fuel as fired after allowance is made for evaporating the moisture in the fuel. This test, which was made on the automatically stoked furnace before referred to, showed an efficiency of boiler and furnace of 54.4 per cent, based on the total heat of the fuel.

THE DESIGN OF CURVED MACHINE MEMBERS UNDER ECCENTRIC LOAD

By Prof. Walter Rautenstrauch, Published in The Journal for Mid-October

ABSTRACT OF PAPER

This paper is concerned with establishing a dependable method of procedure for the design of the principal sections of curved machine members, such as hooks, punch and shear frames, and the like. The basis for this method of design is the theory of the maximum straining action in hooks devised by E. S. Andrews and Prof. Karl Pearson of London University. Experimental results are submitted in support of the theory. Comparison is made of the maximum straining action predicted by the formula due to Unwin now in common use and by the analysis due to Mr. Andrews and Professor Pearson, with that found by experiments on hooks ranging from 2 tons to 30 tons rated capacity.

DISCUSSION

Prof. Gaetano Lanza. A careful perusal of the articles of Messrs. Pearson and Andrews in Drapers' Company Research Memoirs, containing the formulæ referred to by the author, reveals no flaw in the deduction of the formula for the greatest tensile stress at the section of greatest bending moment, provided it is regarded as a formula which gives the relation between the load on the hook and the tensile stress mentioned, and provided the section of greatest bending moment remains plane.

2 To determine in all cases, however, the relation between the load corresponding to a greatest stress at the above stated section, equal to the tensile elastic limit, and the elastic limit as determined by the methods of measurement employed, would, in my opinion, require a set of tests upon a series of hooks varying in their proportions to a much greater extent than those mentioned by Prof. Rautenstrauch, in which the formula of Prof. Pearson would make the two loads cited nearly equal. An example of such a case, in which this result does not hold, is a set of hooks tested under the direction of Prof. C. E.

Fuller, which were really open links of circular form, made by bending hot and annealing square bars, the side of the square being 0.75 in., where $\rho_0 = 3$ in., and where the load at the elastic limit, as determined in a similar manner to that pursued by Prof. Rautenstrauch, was 1100 lb.

3 For these hooks we should have $\gamma_1 = 1.0074$ and $\gamma_2 = 0.00658$.

4 The greatest tensile fibre stress at the section of greatest bending moment, if computed by the ordinary formula, would be 48,600 lb. per sq. in. and, if computed by the theory of Messrs. Andrews and Pearson, would be 59,300 lb. per sq. in., whereas the tensile elastic limit of the material was 30,000 lb. per sq. in.

5 In seeking an explanation of these apparently discordant facts the following observations should be kept in mind.

a In a straight beam we should naturally expect the elastic limit as determined by measuring deflections to be greater than that corresponding to a greatest fibre stress equal to the tensile elastic limit, the excess varying with the span.

b The methods used in all the experiments cited have been practically the measurement of deflections.

c The deflections, whether of beam or hook, cannot be determined by computation from the stresses at the section of greatest bending moment only, but depend also upon the stresses at the other sections.

d In the hooks tested by Prof. Rautenstrauch the section of the hook is a varying one in which the stresses at sections other than that of greatest bending moment have not been examined.

Hence it seems to me that before we can consider that a complete solution of this problem has been attained, we need

a A more extended series of tests which shall include a considerable number of hooks of each kind.

b An experimental determination, both for beams and hooks, of the relations between the elastic limit as determined by deflections and the load corresponding to greatest fibre stress equal to the tensile, or compressive elastic limits, in the case of varying spans and other proportions.

CHAS. R. GABRIEL. The results of tests of crane hooks and the figures obtained by the old and new formulæ, to which Professor Rautenstrauch calls attention, are very important as regards crane hooks and similar members of machines. If such members are not as strong as computed by the usual formula for combined bending and tension it is none too soon for engineers to be made acquainted with the fact. This is especially so because of the fact that metal beams of solid cross section, similar to the cross section of a crane hook when subjected to simple bending, show greater strength than that due to computation, at least when subjected to a breaking test. This excess of strength is so great, especially in beams of cast iron of certain cross sections, as to justify confidence in lesser dimensions for straight beam members than those that would be prescribed by calculation based on the tension and compression moments of beam sections. Similar excess over calculation, of ultimate breaking resistance by test, exists in shafts subjected to torsion.

2 One would naturally expect to find a similar excess of strength in crane hooks when put to test, but the results to which consideration is invited show quite the reverse to be the case, and are none the less valuable because disappointing.

3 As regards machine members, such as the overhung frames of presses, punching and shearing machines, etc., the large majority of such frames require to be rigid under their working loads, to an extent that renders them perfectly safe from failure by breaking. A great many points have to be considered with respect to dies being thrown out of line by the springing apart of the upper and lower arms of the frames. A small amount of such deflection would in some cases be sufficient to cause the shearing of expensive punches by the dies, rendering them unfit for the accurate work intended. In some few other cases, such as riveting, a comparatively large amount of deflection is permissible, and in some instances the proportions of a frame may be considered with respect to safety from rupture alone.

4 The cross sections of overhung frames must of necessity differ a great deal in different machines, also the relative amount of overhang or throat, depth of gap and general form of frame, whether curved similar to a crane hook, or extending straight up and down comparatively short or long distances. Various kinds of cross section such as solid rectangular, T, H, box or combination of box and rib, all have their appropriate uses. The successful designer has at times to depart considerably from formulæ that have been in use and must combine much practical judgment and observation in his work.

Factors of safety must vary from 3 to 50 or more, and stresses accordingly.

5 It is hardly to be expected that a formula for strength of crane hooks can be immediately applicable to all the various cases of overhung machine frames, but we judge it might be applicable to small frames of solid section and short overhang. Frames having a long overhang, such as represented by Fig. 1 in the paper, would in our opinion be a more trustworthy subject for the application of the useful bending formula than frames having relatively a much shorter overhang, such as indicated by the dimensions in Fig. 4. This is because the greater the overhang the more significant becomes the simple bending moment and the less significant the direct tension in the back of the frame.

6 Referring to Fig. 4, it is noticeable that the metal in the back of the frame is very thin. In frames where rigidity is the prime consideration, we believe it is a common error of designers when using cast iron to place too little material in the back. This no doubt arises from the known high compressive resistance of cast iron, without regard to its elasticity under compression; frames being designed accordingly, with regard to resistance to breaking rather than with regard to resistance to deflection. We have known of many cases where frames could be greatly stiffened by merely taking metal from the front web and putting it on the back web.

Prof. Wm. H. Burr. Professor Rautenstrauch has added a very interesting chapter to the lirerature of this subject, but there is perhaps a little more to the matter than has been indicated, and it bears a good deal upon what has been said by the last speaker. Doubtless the analysis based upon Professor Pearson's paper, as an analysis, is a decided improvement upon the Unwin formula, but again there comes in the same question raised in connection with reinforced-concrete beams. This analysis, whether by Professor Pearson or Professor Unwin, is based upon what is ordinarily known as the common theory of flexure, which belongs accurately only to straight beams of very small depth in comparison with the length.

2 Hooks and all such members as those shown by the author are exceedingly short as beams, and they are also curved. These conditions completely demoralize the analysis as based on the common theory of flexure, and it is not a matter of surprise that hooks should show so much greater carrying power than the computations would indicate. In fact, it is precisely in line with what we find in other short beams.

3 The pins at the panel points of pin-connected bridges are designed by the common theory of flexure. Yet if one should compute the extreme fibre stresses in those pins at some panel points as they have existed, they would be found to run up not only to 142,000 lb. per sq. in., but to 180,000 or 190,000 lb. in structural steel. A partial explanation lies in the fact that an analysis is used, which, strictly speaking, does not apply to these conditions. The hook and all such members, as well as bridge pins, are short, thick beams to which the usual theory of bending does not strictly apply.

4 Again, one will find that in bridge specifications, the regular working fibre stresses in pins are permitted to be at least 50 per cent greater than in the tension members of the truss; that is, one may have a working stress of perhaps 14,000 lb. in bars, and a fibre stress in tension of 18,000 or 20,000 lb., sometimes even 24,000 lb. in pins. This is due to a fact I have already mentioned, that as a matter of accurate analysis, the common theory of flexure should not be used in connection with such members; but there is nothing else to be done.

5 That again brings me back to the same point made in connection with concrete beams. The proper procedure is to settle upon some sensible working formula, just as we do in connection with the pins in bridges, make tests of such members, and deduce from these tests such empirical quantities as may be properly used in the formula, so as to make the results of the analysis in that way conform to safe and sensible practice.

George R. Henderson. That we get a rather greater strength than would be expected by the Unwin formula, especially in the case of hooks, agrees with my practical experience. A few years ago we purchased some 60-ton cranes, and when it came to the detail of the hook to lift the 60 tons, the design submitted by the manufacturers was for a hook smaller than we thought would be good practice to accept. We calculated to reduce the total strain due to the vertical stress and the bending moment to about 12,000 lb., which we considered would give a factor of safety of five with the material used. It was pointed out that the hook did not conform to the specifications, and that a larger hook was desired. These larger hooks were provided and they looked gigantic.

2 A little later the question came up again, when the manufacturers stood on their dignity and claimed that the hook was stronger than my calculations showed, and to confirm their case referred to

tests at the Watertown Arsenal, which we all consider pretty good authority. The hook tested was rated as a 20-ton hook, but it had been subjected to a weight of 162,000 lb., at which it merely bent but did not break.

3 These tests were to determine the ultimate strength, whereas the paper deals with the elastic limit; but practically, I think, the ultimate strength interests us as much as the elastic limit. By the regular Unwin formula, which has been somewhat condemned this evening, the stress per square inch in the hook, when weighted to 162,000 lb., at which it simply opened, would indicate 142,000 lb. per sq. in. fibre stress, which, of course, is absurd. So, from the actual tests, it is very evident that the hooks are considerably stronger than the Unwin formula could indicate. In discussing this matter with well known machinery builders, such as William Sellers & Company, we found that while the strain on the hooks might figure at 17,000 lb. per sq. in., from the formula, and show a factor of safety of only three, actually the factor of safety must have been five or six.

4 If possible, I would like to know how the author can reconcile these facts, compared with the practical ultimate strength tests, in connection with the elastic limit.

A. L. Campbell.[1] Table 2 of Professor Rautenstrauch's contribution shows an excellent agreement between actual test conditions and the results obtained by the formula which is the basis of his discussion.

2 A much simpler formula is used by the writer for similar computations. A crane hook or the frame for a punch is really a tension member with an exaggerated eccentric load. The maximum unit stress in such a tension member may be proved equal to

$$f_t = \frac{W}{A}\left(1 + \frac{l\,(1 - e)}{R^2}\right)$$

using the author's notations. The radius of gyration, R, is equal to $\sqrt{\frac{I}{A}}$. Applying this formula to the frame shown in Fig. 4 gives $f_t = 7600$ lb. per sq. in. This stress is 90 per cent of that given by the more complex formula.

[1]The Solvay Process Co., Detroit, Mich.

Frank I. Ellis. While the paper, together with the article in the American Machinist to which it refers, covers very fully the design of hooks, giving results which agree remarkably with actual tests, its application to shear housings is not quite clear to us.

2 We note primarily, that in the derivation of his formula the writer has assumed the entire area to be in tension i. e., the neutral axis to lie entirely without the section. While this condition is almost universally correct in hooks, it will seldom be encountered in shear housings, but still it appears to have important bearing on the form of the equations.

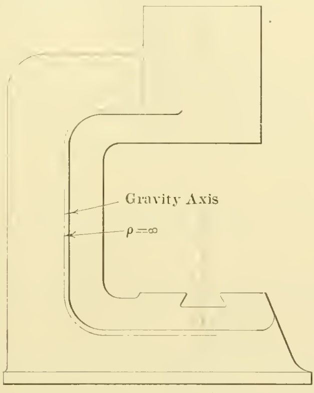


Fig. 1 Frame with Infinite Radius

3 Another point which is not quite clear to us, but is a matter of great importance, is the assumption of the value of ρ, the radius of curvature of the gravity axis of the section. In the case of a hook, this of course is quite obvious, but in machine members, such as shear housings, this seems far from being the case. For instance, in a housing of the general form of sketch shown in Fig. 1 herewith, we would have an infinite value of ρ. This would reduce the formula to a case of simple tension, which is obviously incorrect, giving stresses that would be very much less than would be obtained by actual test. On the other hand, if we consider an extreme case as per Fig. 2, where the value of ρ is very small, the stress as calculated by the formula

would be very much in excess of what could possibly exist in the actual casting.

4 The example of a shear housing which Professor Rautenstrauch has chosen as an illustration appears to us to be at variance with our experience. The stress calculated by the new formula is almost three times that obtained by the usual methods of computation. In our experience, cast iron shear housings in which the calculated

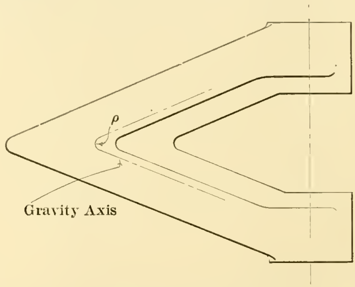


Fig. 2 Frame with Small Radius

stress is 3,000 lb. per sq. in., never break except through defects in the casting, a condition which could hardly exist if the actual stress were in the vicinity of 9,000 lb.

5 In conclusion we may say, that aside from the seeming obscurity of the paper on the above points, we consider the formula to be of considerable value in the cases it is designed to cover. We regret that we have been unable to give it the time it deserves, and trust the above points will be made clear by the author.

E. J. Loring.[1] The results of the author show such striking discrepancies from the results by the usual methods of calculation that his analysis of the problem merits the most careful consideration. These results clearly show that the stresses and particularly the maximum stress in a curved piece under the combined direct and bending load to which such hooks and gap frames are subjected cannot properly be deduced from the simple combination of direct and bending stresses as determined by ordinary analysis from the stresses in a single plane, but may be influenced to a greater extent by con-

[1] Loring Speed Gauge Co., 76 Highland Ave., Somerville, Mass.

ditions outside of the section plane, such as the relations connecting that plane with those nearby on either side.

2 This difference between straight and curved members arises from a different distribution of stress due to the variation of length of fibres at different parts of the section as taken between similar adjacent sections.

3 The usual deduction for stress in straight members commonly applied to this problem assumes

a Planes remain planes after bending.
b Strain is proportional to the distance from the neutral axis.
c Stress is proportional to strain and therefore the stress is proportional to the distance from the neutral axis.

4 The assumption that stress is proportional to strain is true only as referring to unit strain, as long fibres will yield more under a given stress than shorter ones. In the case of straight members the adjacent minimum sections are parallel and the elementary fibres therefore all of equal length, and the assumption may be applied. In the case of a curved member, which I would define as one in which the locus of the centers of gravity of the minimum cross-sections is a curved line, these sections are not parallel, but radiate from a center of curvature so that the fibres are not of the same length throughout the section, and a correction must be made for the variation of the length of fibre before this assumption can be applied. This point has been generally overlooked or considered negligible, and in this point is to be found the explanation of the difference in results. I might add that this exemplifies the danger of applying a formula to conditions which it was not intended to represent.

5 I am not certain that I can agree with the author in the use of the theory of lateral contraction in the analysis. I cannot at this moment see why it is any more necessary in the case of the hooks tested than, for example, in the case of the test bars from which he deduced the fibre stresses. Taking only the common assumptions, with the correction for the length of fibre, as above noted, it is possible to obtain results in very close agreement with those given by the formula recommended by Professor Rautenstrauch. In place of the usual straight-line diagram of stress on the section these assumptions give the stress at any point as varying according to

$$\frac{y}{1 + \frac{y}{\rho}} \quad \text{or} \quad \frac{y\rho}{\rho + y}$$

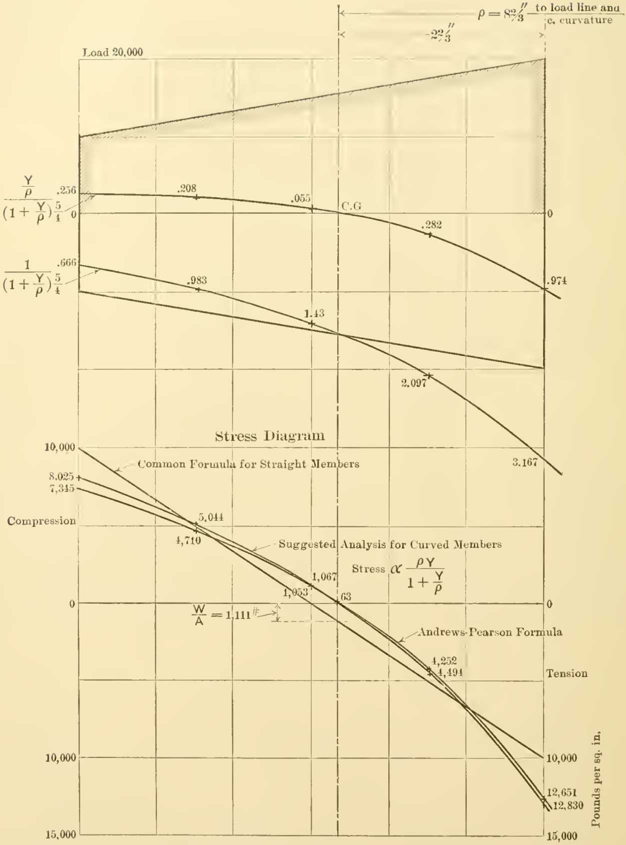


FIG. 1 DIAGRAMS FOR TRAPEZOIDAL SECTIONS OF STRAIGHT AND CURVED MEMBERS FOR EQUAL INTENSITY OF STRESS

using the symbols of the paper, and from this may be determined this important fact; that for the case represented by the hooks, where the line of application of the load contains the center of curvature, the neutral axis contains the center of gravity. In other words, instead of the stress at the gravity axis being equal to the distributed stress as is true for straight members, the stress at this point in a member with this degree of curvature is zero, and this represents the manner in which the stress "piles up" toward the inner edge of a curved member. This condition of stress at the center of gravity would be represented in the analysis of the paper by the condition $\gamma_1 = 1 + \gamma_1$. The empirical formulæ recommended give $\gamma_1 = 1 + 1.1\,\gamma_2$ and the data on the hooks give a variation from $\gamma_1 = 1 + 1.17\,\gamma_2$ to $\gamma_1 = 1 + 0.88\,\gamma_2$ with an average of $\gamma_1 = 1 + 1.015\,\gamma_2$ so that it will be seen that this is approximately true by Professor Rautenstrauch's analysis; that the gravity axis is the neutral axis for this degree of curvature just as it is for transversely loaded beams.

6 I have applied the variation of stress

$$\frac{y}{1 + \frac{y}{\rho}}$$

given above to the solution of an assumed section and find that the stresses and their manner of variation are substantially identical, for this particular case at least, with those given by the author's method. I believe that an analysis can be made along this line that will give results very close to those shown and be more generally workable. The differential expressions for the net stress on the section and the moment of the stress are similar to those for a beam with the addition of a factor

$$\frac{1}{1 + \frac{y}{\rho}}$$

$$W \text{ varies as } \Sigma \frac{y\, dA}{1 + \frac{y}{\rho}} \qquad Wl \text{ varies as } \Sigma \frac{y^2\, dA}{1 + \frac{y}{\rho}}$$

It may perhaps be possible to deduce some general expression to be used as a factor of correction for curvature to be used with the usual methods.

7 The effect of the curvature is less, the greater the ratio of radius of curvature to the depth of section. In the case of hooks this means greater strength where the contour of the inner edge is elliptical instead of circular, so that the curvature at the most strained section is less. As the curvature tends to "pile up" the stress toward the inner edge, greater strength may be had by giving the hook a closer approximation to a Tee section, by which means the metal is massed better where the stresses are abnormally high. It would also appear that a high gap is stronger than a low one for the same depth, since a lesser degree of curvature is possible.

8 I must disagree with the statements in Par. 2 except as limited to curved members; also with the statement in Par. 8 that γ_1 and γ_2 are constants for all sections of similar form, except it be modified to say "of similar form, curvature and load distance." I question the significance of the quantity k in Par. 11, where it is stated to be the radius of gyration, as the value of k given for the punch frame following is the radius of gyration squared, or $\frac{I}{A}$.

9 In determining the maximum stress by the method which the author has proposed, the function γ_2 is the most important factor, and this function is obtained from the difference in area of two derived curves; the difference is small and the less the difference the greater the maximum stress. It would seem that there is great opportunity for inaccuracy in determining this factor. It also appears to me to be simpler to take

$$\gamma_2 = \frac{-\Sigma\left(\dfrac{1}{1+\dfrac{y}{\rho}}\right)^{\frac{5}{4}}\dfrac{y}{\rho}\,\mathrm{d}A}{A}$$

as originally stated for the purpose of the computation, rather than to use the value derived from it, of

$$\gamma_2 = \gamma_1 - \frac{\Sigma\left(1+\dfrac{y}{\rho}\right)^{\frac{1}{4}}\mathrm{d}A}{A}$$

for the reason that having the quantities for the determination of γ_1 for various points of the section, that is, the values of $\left(1 + \frac{y}{\rho}\right)^{\frac{5}{4}}$

it will be simpler merely to multiply these by the respective distances from the gravity axis, plot the curve and integrate for the net area, rather than to proceed by raising the denominator to a new power and passing through all the processes anew.

10 It is stated that the standard section selected for the computation of constants for the empirical formula is not the most economic from the standpoint of equal tension and compression stresses. This is true even if the member is straight, in which case, considering the trapezoid only and omitting the curved ends, the maximum stress in compression is 85 per cent of the maximum stress in tension. All other parts remaining the same, for equal intensities of stress in the edges for a straight member, the half width of the narrow edge should be 0.095 r, as may be very readily demonstrated. The geometrical relations for the correct proportions of a trapezoidal section for equal intensity of stress in a straight member are so exceedingly simple that I want to give them here, particularly since so far as I know they have never been published. This relation is that the sides extended intersect at a distance from the far or narrow edge equal to the distance of the load line from the near or wide edge, and for the solution of this case we have

$$d = \sqrt[3]{6\,ky\frac{F}{f}}$$

where d = depth of section

y = distance of load line from the near edge

F = load

f = maximum stress at the near edge or far edge (equal)

and k is a design constant = ratio of depth of section to width of far edge.

11 For the case of equal stresses in a curved member of trapezoidal section with center of curvature on the load line, a similar relation may be deduced from the analysis that I have here suggested, but is not quite so simple: the point of intersection of the sides is given by the following construction. Lay off on the axis of symmetry and toward the far edge a distance from the *near* edge equal to the distance from the near edge to the center of curvature and load line. If this distance is greater than the depth of section, equal stresses may be had. If this distance is equal to the depth of section; i. e., if the point thus laid off is on the far edge, equal stresses require a triangle with this point as the apex. If the point is beyond the far edge,

divide the distance to that edge in thirds; then the stresses are equal when the sides extended intersect at the nearer point of division, one third of this distance from the far edge.

12 It will be noticed that this construction gives the radius of curvature for this limiting case[1] equal to 1.33 times the depth of section[1] instead of 1.75 as given by Professor Pearson. I have investigated this case for both degrees of curvature by the method involving the lateral contraction and find that using the formulæ given by Professor Rautenstrauch the curvature of 1.33 times the depth, measured to the gravity axis, gives a stress on the inner edge of 1.091 times that on the far edge. A similar operation for curvature of 1.75 as recommended by Professor Pearson, by his own method gives by my computations a ratio of stress of 0.912. A sharp triangular section such as this is however of little or no importance in actual construction, and the method of determining the proportions which I have given will, I think, be found to be of much more general application. I am unable to state at the present time whether a section having equal intensity of stress on the two edges is or is not the most economical of material; but presumably it is.[2]

Prof. C. E. Houghton. The agreement between the elastic limit as calculated by the proposed formula and that as derived from the tests, is to say the least, wonderfully close, and the wide variation between the experimental values and those calculated by the use of a theory that has been in common use for many years leads one to ask "Why are there not more failures in crane hooks?"

2 Objection has been made to the tests because the hooks were not loaded beyond the elastic limit. This seems to the writer to be a mistake. What the engineer is mostly interested in is the effect of loads that produce stresses within the elastic limit, since the great majority of the formulæ used for the calculation of stresses are based on theory that no longer holds true after the elastic limit has been exceeded.

3 Professor Burr has pointed out that the simple theory of flexure does not apply to curved members and Mr. Gabriel notes that stiffness and not strength is the controlling factor in many of the open-side machine frames. May not the fact that cast iron is used in the majority of such frames be another reason why the flexure formulæ cannot be expected to give correct results? The well-known fact

[1]Or depth of section equal to gap depth.

[2]Since writing the foregoing, Mr. Loring has found that the method suggested by him for the determination of the stresses—or a very similar one—is given in some detail in Hütte, from some German source dating 1902.

that the physical properties of any cast iron vary with the rate of cooling, and that the tensile strength and modulus of elasticity are not constant at all depths from the surface of any cast iron member, but vary throughout any given section, leads one to ask "Is it not more reasonable to use the simpler formulæ in the calculations for strength and to provide against possible errors by that useful and elastic term—the factor of safety?"

H. Gansslen.[1] The author's tests prove the correctness of Andrews and Pearson's new formula for figuring crane and coupling hooks. All the experimenters, however, seem to have limited themselves to these hooks, for which the formula appears to have been gotten out. Hook's law of the direct proportionality between stresses and strains also underlies the new formula and the fact that this law holds practically good on wrought iron, steel and similar materials would to some extent explain the good agreement of the results of tests and calculations by means of the new formula.

2 The author points out that the formula is applicable to punch and riveter frames. To generalize thus I believe is hardly wise at present, as all the various formulæ for figuring curved beams are more or less empirical and each of them is naturally proved to be true for a certain limited field of calculations only. Hook's law does not hold true for copper, cast iron, bronze, stones artificial and natural, etc., and this law giving the modulus of elasticity as constant is the basis of the formula.

3 Engineers know that the old formula for figuring a curved member in the same way as a straight beam gives too small factors of safety, but that we are now under-estimating the stresses in the throat of punch press frames $8500 \div 2450 = 3\frac{1}{2}$ times is surely saying much.

4 However, there is no use disputing the new formula in so far as tests have verified it and it is to be hoped that the author will have the opportunity of entering other fields of research besides that of crane hooks, and that of press frames would be a desirable one.

5 I have not come across a case where a punch press frame figured in the usual, but wrong way could have been $3\frac{1}{2}$ times under-estimated, roughly considered, by comparing the pressure exerted with the general behavior of the frame.

6 The old theory of flexure as applied to and compared with tests of cast iron has shown its inapplicability and this should make us all

[1] Mechanical Engineer, 404 Fisher Building, Chicago.

the more cautious in adopting the new formula for cast iron press frames before having the results of tests on hand that would justify us in so doing.

John S. Myers.[1] The author's presentation on the design of curved machine members and his article in the American Machinist of October 7, 1909 dealing exclusively with crane hooks, seem to indicate that the new theory is applicable to punch and riveter frames of the type shown in Fig. 1, where the throat is semi-circular, being struck with a radius having its center at O. In order, however, to find the radius of curvature of the gravity axis of the principal section it would seem necessary to plot points such as A, B, C, D, E, draw a curve through them, then, by trial, find the center O' of a circular arc which will pass through C and most nearly fit the curve for points intermediate between B and D.

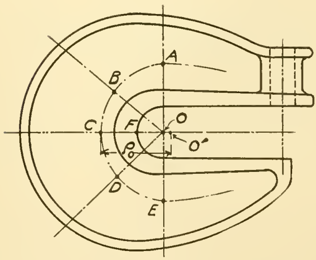


Fig. 1 Frame with Semi-Circular Throat

Curve $ABCD$ represents the gravity axis of the section. Point O is the center of the throat radius. Point O' is the center of a circular arc which approximately coincides with the gravity-axis curve for points between B and D.

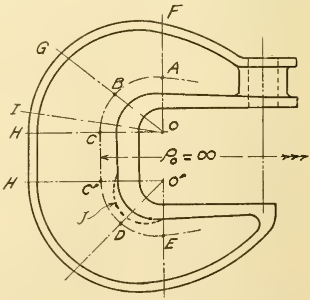


Fig. 2 Frame with Wider Gap than Fig 1

Curve $ABCC'DE$ represents the gravity axis. Between points C and C' this curve becomes a straight line; hence $\rho_0 = \infty$

2 If the above is consistent with the assumptions upon which the theory is based, it will be seen that the point O' is not necessarily coincident with O, and that to find the value of ρ_0 a layout must be made and the gravity axis of several sections determined. It

[1] John S. Myers, 2456 Almond St., Philadelphia.

is also seen that ρ_0 is not strictly a function of the throat radius nor is it equal to $OF + CF$ as one would at first suppose. This adds more complication to the problem, which is already vexatious.

3 Again, such frames are not always made with the throat struck with a single radius; in fact, this is the exception rather than the rule for quite a large class of machines, which have a wider "gap" to accommodate the work and are more like that shown in Fig. 2. Here the curve representing the gravity axis is a straight line between points C and C', in consequence of which $\rho_0 = O, O$ and it would therefore seem that the new theory did not apply to this portion of the frame. Now, if this be the case, and we design that portion of the

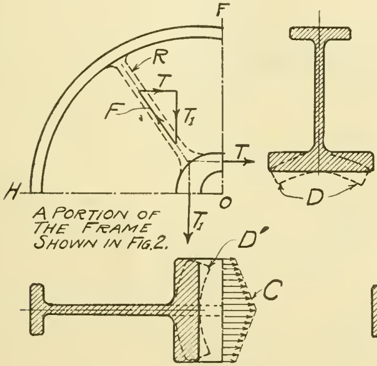


FIG. 3

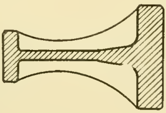


FIG. 3a

FIG. 3 SHOWING HOW THE RAPID TRANSITION OF STRESSES INDUCES LOCAL STRESSES. FIG 3a. PROPOSED SECTION

frame between OH and $O'H'$ according to the old theory of straight beams, but design section OI according to the theory of curved beams under discussion, it would appear from an inspection of the results given by Professor Rautenstrauch that section OI should have about three or four times the flange area of section OH. Of course the metal at the corners could be thickened, as indicated by the dotted line at J, but it would be out of the question to double or treble the usual flange thickness, which is what the new theory seems to indicate as necessary.

4 It would be very interesting to know how the new theory could be properly applied in such a case; whether, for instance, it is entirely applicable at the section OG but gradually merges into the old theory

at sections OF and OH; or whether it has not, as yet, been sufficiently developed to be generally applicable to sections other than those at right angles to the line of action of the force.

5 Generally speaking, a structural engineer never puts in curved tension or compression members because he knows that force either travels in straight lines or else produces bending strains; but the average designer of machinery seems to delight in curved ribs, bent levers, and the like. The average mechanical draftsman makes layouts as if he held the opinion that force travels along a curved rib in a manner somewhat similar to water flowing in a pipe and that it

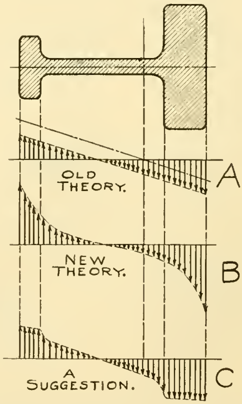


Fig. 4 Distribution of Stresses Under Different Theories

will, therefore, follow any devious or sinuous course in which he may choose to distribute the metals. Most C-frames seem to be designed on the foregoing assumption and, while it is an exceedingly difficult piece of mental gymnastics to follow the mathematics of the new theory, it is, however, quite easy to see that there are stresses induced in curved ribs which are usually ignored.

6 To illustrate the foregoing, Fig. 3 shows that portion of the frame of Fig. 2 which lies between lines OF and OH. Now, let T and T_1 represent the total tensions in the flanges on sections OF and OH respectively. By combining T and T_1 graphically it is seen that a resultant force F must, in some manner, be supplied to establish equilibrium. The most direct way of supplying such a force is by

the addition of a rib as indicated by the dotted lines at R which will distribute part of F into the web and deliver part of the force at the compression flange where there is a smaller, opposing resultant force. In the absence of any such rib the necessary force must be supplied by the web, partly through a local bending and distortion of the flanges as indicated by the dotted lines at D and D' and partly by a concentration of stresses towards the central portion of the flanges as indicated at C, this concentration being a direct result of the deformation at D'.

7 In supplying a rib R, if it was intended to carry the entire force F it would be necessary to make it about $1\frac{3}{8}$ times the average thickness of the flanges, but since the web can readily take half, or more than half, of the load it would seem that a rib of $\frac{5}{8}$ or $\frac{1}{2}$ of the flange thickness, narrowed down at the center as shown in Fig. 3a would be entirely sufficient, especially if the web be judiciously thickened and liberal fillets used.

8 As I understand the new theory it does not recognize any such concentration of stresses as indicated at C in Fig. 3 but, on the contrary, assumes a more rapid concentration towards the extreme fibres in a manner somewhat similar to that shown at B in Fig. 4. Now in view of the close accord between the new theory and the results of Professor Rautenstrauch's experiments, I am quite ready to believe that diagram A represents quite closely the actual conditions for straight beams of solid section, and that diagram B represents the most plausible theory for curved beams of solid section; but that for beams composed of heavy flanges and a light web the probable distribution of stresses is more nearly like that suggested by diagram C, and that so far as the curved form of the beam is concerned, it is not the curve of the neutral axis we are interested in but the curve of the flanges, and that this results in local bending and concentration of the stresses as already pointed out.

9 I have no well formulated theory to advance in explanation of my belief in a distribution of stresses like that indicated by diagram C but have sufficient faith in it to calculate sections of this nature by the very simple process of considering the stress to be uniformly distributed over the flange area and entirely neglecting the web; then at points where there is rapid transition of stresses, supplying ribs, thickening up the web and allowing a lower flange stress and liberal fillets. This procedure may sound crude to a scientific man, but it has, at least, ease of application in its favor and may yet be shown to be actually more scientific than the more laborious methods

usually pursued. As yet, I have not had the temerity to apply this method to large work but would like to have the opinion of those who have had experience along these lines.

The discussion concluded with an interesting talk by Carl G. Barth illustrated by a blueprint and blackboard sketches. Mr. Barth has not been able to prepare this for publication. Editor.

The Author. The test reported by Professor Lanza is interesting, but I do not feel justified in replying without a review of the entire data on the experiment. The point made by him in Par. 5 in regard to deflections, is somewhat misleading. I did not propose in my experiments to determine the relation of total deflections to the maximum stress in the hook, but rather to find the load at which the total deflection ceased to follow the straight-line law. Since the total deflection is dependent on the deflection of all the sections, it is rational to suppose that when any variations occur they are due to the fact that the "fibres" in the most strained section have been stressed beyond the elastic limit. This is all we wish to know. The most strained section is without doubt the main horizontal section. The examination of the bending moments in other sections is of no value in these determinations.

2 Referring to Mr. Gabriel's remarks: I regret that so many designers persist in applying the formulae for determining maximum intensity of stress beyond their limits of application. No computations can be made to determine *ultimate breaking strength* and I see no reason why anyone should be surprised that there is a disagreement between the "results of computations" and the results of test. I did not choose to consider the matter of rigidity, which the title of the paper would lead one to believe should be included. Rigidity is, of course, a controlling factor in die work. The dimension of the metal in the back of the frame shown in Fig. 4 of the paper should be $1\frac{1}{4}$ in.

3 Mr. Henderson's remarks that his practical experience with hooks leads him to believe that a rather greater strength exists than can be expected from the Unwin formula, qualified by his report of certain tests, would lead one to believe that he has made use of Unwin's formula outside of its field of application. Unwin's formula indicates nothing beyond the elastic limit. There exists no method of analysis which enables us to determine the relation between the load on the hook and the resulting maximum intensity of stress

when that stress is beyond the elastic limit of the material. In reply to the statement that "the ultimate strength interests us just as much as the elastic limit," I would say that I believe designers will be treading on much safer ground when they confine themselves to proportioning parts with a factor of safety based on the elastic limit rather than the ultimate strength.

4 Mr. Ellis says in the second paragraph "We note primarily that in the derivation of his formula the writer has assumed the entire area to be in tension. i. e. the neutral axis to lie entirely without the section. While this condition is almost universally correct in hooks it will seldom be encountered in shear housings." No such assumption is made, nor is it universally correct in hooks. I believe that Mr. Ellis is also mistaken in his remarks on the particular form of the equation when ρ is infinite. When ρ is infinite the case is not that of simple tension but rather as expressed by Unwin's formula.

5 Mr. Loring's explanation of the two analyses, I regret to say is incorrect. Both analyses are founded on a determination of the relation between *unit* stretch and intensity of stress, but the real difference is found in the methods of evaluating the unit stretch. The older formula gives the *unit* stretch as

$$\lambda_y = \lambda_\beta + \frac{y'}{\rho'}$$

while the newer analysis gives

$$\lambda_y = \lambda_\beta + \frac{\dfrac{y'}{\rho'} - \dfrac{y_0}{\rho_0}}{1 + \dfrac{y_0}{\rho_0}}$$

where

λ_y = unit stretch of any fiber a distance y^1 from the gravity axis.

λ_β = unit stretch at gravity axis.

ρ' = radius of curvature at gravity axis after stretching.

ρ_0 = same before stretching.

y_0 = modified y' after stretching.

The newer analysis retains terms of the same order of magnitude as λ_y and therein lies the difference. The theory of lateral contraction is rationally applied in this analysis, its application being unnecessary to the test piece, since direct measurement of stress is made.

6 Par. 2 in the paper is obviously limited to curved members. The similar form referred to in Par. 8, includes the radius of curvature.

7 In Fig. 4, $k^2 = 68.56$. In Par. 13 the equation should be $\gamma_2 = \frac{k\,e}{0.7\rho^2}$. The method uesd for determining γ_1 and γ_2, I believe will be found more convenient than those proposed by Mr. Loring.

8 Professor Houghton will agree with me that a more correct analysis for straining action will permit a more intelligent use of the factor of safety.

9 Mr. Myers is quite correct in his remarks on the value of ρ_0. The analysis, however, does apply to the case of straight beams where $\rho_0 = \infty$, for which case it reduces to the form of the Unwin formula. The formula has not as yet been sufficiently developed to determine its usefulness in establishing proportions for other than those sections at right angles to the load. The difficulty of determining the stretch on sections at an angle to the load will leave this problem unsolved for some time. It is, however, rational to suppose that the flange on oblique sections should be thickened, but to what extent has not yet been determined. In regard to the behavior of a T-section, I would state that Professor Pearson has found experimentally that it is subjected to the same laws as a solid section. This indicates that the suggestion of Mr. Myers in Fig. 4 can hardly be accepted.

10 I judge from Professor Burr's remarks that he discredits the analysis by Professor Pearson on the basis that it is founded on the common theory of flexure, that is, it is not applicable to beams of very great depth compared with the length. I believe that if Professor Burr had given more thought to the matter he would not have made this statement. In view of the experimental results obtained by myself and others in verification of the theory and the lack of any data in verification of Professor Burr's statement, I am still inclined to believe that Professor Pearson's analysis is correct.

VENTURI TESTS FOR BOILER FEED

By C. M. Allen, Published in the Journal for Mid-October

ABSTRACT OF PAPER

The object of these tests with the venturi meter was to determine how well adapted it would be for use in measuring the feed to a boiler, in view of the variety of conditions under which it might have to operate. The methods of pumping the water through the meter, the different temperatures of the water pumped, various and fluctuating pressures and velocities of flow,—any one or several of these conditions might be met with in actual service, and the results obtained indicate that such occurrence would have practically no effect on the satisfactory performance of the work of the meter.

However, there are limits to this satisfactory operation of any one meter, and the lower limit for this size seems to be reached when the velocity of the water through its throat becomes lower than about 10 ft. per sec. In case the desired amount of water is smaller than the quantity which would produce this velocity in the meter, a smaller meter would be installed. It is evident from these tests that the venturi meter is sufficiently accurate for the majority of commercial or engineering requirements.

DISCUSSION

F. N. Connet. I think that the coefficients shown by Fig. 2 are slightly less than they ought to be, because I suspect that the "venturi head" was considered equal to 13.6 times the difference of the mercury levels in the manometer, whereas this ratio is actually 12.6. Correcting for this difference would slightly increase the coefficient and would make it correspond more closely to those obtained in our own experiments.

2 The correction necessary for difference in temperatures is not as great as with mechanical meters, for the reason that the venturi meter itself automatically compensates for one-half of the difference in specific gravity. In other words, if the water be hot and the specific gravity 2 per cent less than that for which the meter was calibrated, a correction of 1 per cent is automatically made by the meter and therefore a further correction of only 1 per cent is necessary, whereas, with a mechanical meter depending upon volumes, a correction of 2 per cent would have to be made if the readings were desired in pounds. The

reason for this difference between the two types of meters is that the flow through the venturi meter is proportional to the square root of the venturi head and is not directly proportional to it.

3 The only reason for not always obtaining accurate results with the venturi meter for boiler feed is the presence of severe pulsations in velocity due to the action of the feed pump. The most accurate results can be obtained when the feed pumps are of the centrifugal type and many such pumps of the two-stage or three-stage turbine variety are now in successful use. The pulsations which are due to the action of the water plungers or to defective valve action in a reciprocating pump, make it necessary to place a rather large air chamber directly on the pump, or on the feed line as close as possible to the pump. If placed on the feed line, it should not be connected on a tee set in the line but it should be so arranged that all of the water will pass through it. Furthermore, the cross section of such an air chamber should be large and the arrangement should be such that the surface of the water will rise and fall with each stroke of the pump, There should be a gage glass on the side of the air chamber so as to insure the presence of a sufficient vacuum of air. These precautions will render the velocity of the water sufficiently uniform to obtain accurate results with the venturi meter.

4 I notice also that the results obtained were not very satisfactory when pulsations were present and when the throat velocity was less than 10 ft. per sec. There were three reasons for this which seldom if ever exist in actual venturi meter installations:

a The instrument used in the test was a mercury U-tube or manometer, containing but little more than a pound of mercury. The inertia of the mercury was therefore small and the mercury levels were unsteady. In an actual installation a registering instrument is generally used which contains almost 100 lb. of mercury, the mere inertia of which has a decided "damping" effect.

b The graduations on a manometer scale are quite close together at low throat velocities. At 10 ft. per sec. throat velocity, the difference of mercury levels is only 1½ in. In the registering instruments the movements are increased by a lever so that accurate readings are facilitated.

c During the tests described in the paper, the globe valves in the two pressure pipes were partially closed to minimize the mercury level fluctuations, and in all probability the valve discs were slightly loose on the valve stems. This therefore allowed the discs to behave like check valves

and permitted a freer flow in one direction than in the other; consequently incorrect mercury levels would result.

5 There are at least three better ways to throttle one or both of the pressure pipes than by using globe valves. The first and perhaps the best way is to use a capillary tube, say $\frac{1}{8}$ in. inside diameter by two or three feet long. The second way is to use a needle valve which is similar to a globe valve, but without a loose valve disc and with a long tapered point directly on the valve stem. The third way is to use a cock instead of a valve. Any of these methods of throttling combined with an ample air chamber permits accurate venturi meter readings at throat velocities as low as 2.8 ft. per sec. This extends the range of the meter from its maximum capacity down to one-thirteenth of the maximum.

6 Although a manometer, because of its portability and simplicity, is particularly well adapted to the making of short boiler tests, it nevertheless is not automatic and it shows the rate of flow only at the moment of observation, and if this rate fluctuates considerably from minute to minute, it becomes necessary to take very frequent readings. For this reason an instrument has been perfected which has two dials, one for indicating the rate of flow and the other for continuously recording this fate upon a circular chart paper. A special planimeter enables the charts to be measured so as to obtain the total quantity of water. This planimeter multiplies the factor of velocity by the factor of time and the product, of course, represents quantity. This type of recording instrument is largely used for meters 4 in. and smaller in diameter but for larger size meters the users generally prefer a three-dial instrument of the integrating type in order that the total quantity of water may be read directly upon a revolution counter without the aid of the planimeter.

Clemens Herschel. Professor Allen's paper shows, by tests properly and skillfully made, that the meter is reliable for hot water and boiler-feed service, and is new and unique as reproducing in tests of the meter the curious conditions to which a boiler-feed water meter is subjected. But for this feature the tests would have been only a repetition of other tests already made. Not that such repetitions are not desirable, especially when made as accurately and with the scope and purpose of those given in Professor Allen's paper. Further series of rests on venturi meters of all sizes, are in fact still called for in the interests of exactitude. But they can only in a general way confirm, not discover.

2 The point to be considered is, that several thousand venturi water meters are now in use, the world over. They are the embodiment of the action of one of the laws of nature, and are but little dependent on a correction by coefficients. They have been tested in various sizes, from $\frac{1}{4}$-in. to 10-ft. main pipe diameter, and operate exactly alike in all these sizes. They are also used to meter gases, brine and chemicals, and, as we see from the paper, to meter hot water. It is indeed a curious circumstance, that while the inventor and the manufacturers of the venturi water meter never expected to see many of these meters of less than 12 in. diameter used in practice yet the demand for hot-water boiler-feed meters has exceeded in value that of all the other sizes, for certain periods.

Sanford A. Moss. I understand from Par. 7 that the discharge of the venturi meter was figured on the basis of cold water with standard density in all cases, and that the theoretical effect of change of density was not taken into account in the formula. This would mean that Professor Allen's curve takes account of the effect of density changes, as well as all other changes. The actual formula used, and a sample of the calculations, might be a desirable addition to the paper.

2 Assuming that the above interpretation is correct, Professor Allen's curve shows that the actual flow in pounds per hour, with a given pressure, increases as the density decreases, due to rise of temperature. Is this not surprising? Theoretically, flow should decrease with the square root of the density. Of course change in the orifice friction coefficient, due to change of density, temperature, etc., might occur to such a great extent as to overbalance effect of density change. The actual orifice friction coefficient would then have a greater upward slope than in the chart so as to be over 98 per cent at 200 deg. Orifice friction coefficients for all density conditions and all fluids are usually the same for velocities occurring in practice, which are always above the "critical velocity" where fluid adjacent to a wall is stationary and where viscosity is a factor. Thus the orifice coefficient for air is the same as for water, even though the density is decreased about 800 times.

F. N. Connet. If I understand Dr. Moss correctly, he states that the quantity decreases as the density increases. With the venturi meter this depends upon the character of the graduations. If the units are cubic feet the readings *decrease* in proportion to the square

root of the increase of density, but if the units are pounds the readings *increase* in proportion to the square root of the increase of density. One is exactly the reverse of the other.

Geo. A. Orrok. I note that Professor Allen has obtained results for the coefficient of the venturi meter similar to those given by Clemens Herschel in his paper presented before the American Society of Civil Engineers, December 21, 1887, the lower values of the coefficient appearing at a velocity of about ten feet per second.

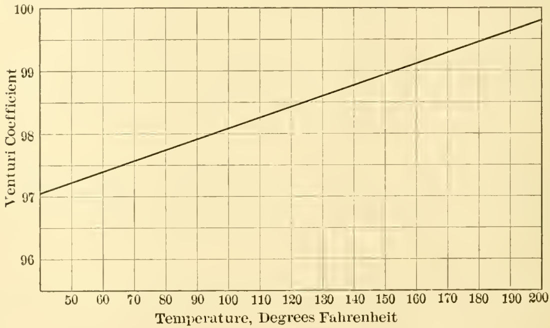
2 The New York Edison Company for some years has been using venturi meters for the measurement of water. We find them accurate and very convenient. For the last three years we have been using them in the testing of our boilers, having conducted a series of check experiments to determine the variations with temperature. Our condition is considerably better than Professor Allen's, since we use centrifugal feed pumps and consequently have a steady reading on the manometer.

3 In cases where we have both weighed and measured the feed water our results were remarkably close. On a 7-hr. test, where about 170,000 lb. of water was fed to the boiler, the meter exceeded the weighing by 631 lb., or approximately 0.37 of one per cent. In another test, in which nearly 200,000 lb. was fed, the difference was about 0.47 of one per cent. I believe the meter readings are more nearly correct than the weighing, as there was considerable opportunity for evaporation from the tanks in which the weighing was done.

The Author. Mr. Connet is correct in his statement concerning the coefficients of the venturi meter, relative to temperatures as shown in Fig. 2. There should be a correction. Each coefficient should be multiplied by the factor 103.8. This raises the coefficient to much nearer unity. The curve herewith shows the relation between the values of the coefficient for the varying temperatures.

2 I agree with Mr. Connet in regard to the throttling of the water in the pipes leading to the manometer. I believe the needle valve, or a fairly long pipe of small diameter, would be a decided improvement over the globe valves which were used in these experiments. We had not discovered that the movement of the end of the globe valves affected the reading, but Mr. Connet has had a good deal more experience along these particular lines, and I am perfectly willing to believe that this is true and that these fluctuations could be materially cut down and yet give the true mechanical average. This is

what we are looking for, and it is a good deal better than using maximum and minimum readings and then obtaining the arithmetical average. The mechanical average obtained by means of throttling is certainly more accurate because we do not know how long the maximum deflection continues, relative to the minimum.



Curve Showing Variation of Venturi Coefficient with Rise in Temperature

3 For the benefit of Mr. Moss, I would state that the density at different temperatures was considered. The following is a sample test giving an idea as to how computations were made:

If W = actual weight of water from weighing tank, then

$$W = 60\, w\, a\, C\, t \sqrt{2gh}$$

w = weight per cu. ft. at the temperature
a = area venturi throat
C = venturi coefficient
t = time in minutes
h = venturi head

$$C = \frac{W}{60\; w\; a\; t \sqrt{2\, gh}}$$

$$C = \frac{W}{1.48\; w\; t \sqrt{h}}$$

DATA OF TEST

Time 3:40 – 3:51; duration 11 minutes.	lbs.
Weight of tanks at beginning	1158
Weight of tanks at end	5369
	4211
Deduct for tank calibration	20
	4191
Add for evaporation	2
Total water	4193
Mean mercury deflection	17.24 in.
$h = 1.05 \times 17.24$	$= 18.1$ ft.
$\sqrt{h}$	$= 4.25$

w for temperature of 137 = 61.43

Weight = $1.48 \times 11 \times 61.43 \times 4.25 = 4250$

$$C = \frac{4193}{4250} = 0.986 \text{ coefficient of venturi meter.}$$

COOLING TOWERS

By J. R. Bibbins, Published in the Journal for Mid-November

ABSTRACT OF PAPER

Developments of recent years of both steam and power plants have demonstrated the usefulness of the cooling tower. This piece of auxiliary apparatus has always been more or less neglected.

It is true that in some plants the maximum effectiveness of the cooling tower and that of the condensing plant are in a sense diametrically opposed—one profits by the shortcomings of the other. The tower works best when the vacuum is lowest. On the other hand this tends to a general operative equilibrium and often saves the day when two interdependent types of equipment would succumb. Fortunately, improvements in condensers is being actively pushed, the trend being to secure higher hot-well temperatures. This immediately enhances the effectiveness of the cooling tower. Similarly, in gas-power plants, the possibility of cooling jacket water by means of this apparatus is favored by the high temperatures of discharge which prevail in engines of good construction. It is not an impossible state of affairs for the jacket water in a gas-power plant to cost more than the fuel, if not cooled and used over again, so that from all standpoints the cooling tower is worthy of careful study.

It is the object of this paper to bring into concrete form for discussion the most prevalent ideas in cooling tower construction, and a simple, inexpensive type employing lath mats is suggested together with suggestions for a combination of natural draft and forced draft types.

The performance data included in the paper are merely to give some idea of the general characteristics of the latter type of cooling tower under various conditions of operation, rather than to represent the results of a highly scientific test.

DISCUSSION

Geo. J. Foran. Evidently Mr. Bibbins has intentionally restricted his discussion to the subject of the paper, the cooling tower. He has, however, presented certain tables which, without discussion, are liable to be misleading with reference to the condensers and general cooling-tower condensing situation.

2 The paper discusses the tower quite fully, but classifies the condenser as good, bad or worse without discussion. This is made possible by assuming that the various condenser results obtained are simply a question of condenser design. This permits the inference to be drawn that the various results can be obtained at the same, or practically the same, cost, which is incorrect. Some of the results stated are possible of attainment, but would not show profitable investment.

3 It is impossible to differentiate the tower and condenser quite so completely as in the paper. Each is strongly influenced by the possible range in operation of the other, and I would like to show just how the relative sizes and consequent costs of the plants will be modified by the results desired.

4 Observers agree that the heat transferred through condensing surface varies directly with the mean temperature difference between the two sides of the tubes. Whether this mean should be arithmetical or geometrical is immaterial for the present discussion, and for simplicity I have selected the arithmetical mean.

5 It is unnecessary to assume condensers of varying grades of design and efficiency; in fact, it hopelessly complicates the question, and for my discussion I have assumed a condenser of uniform design and maximum efficiency with a varying amount of surface, which will permit us to obtain the various results tabulated by Mr. Bibbins.

6 The fairly universal practice for high-vacuum work for the past few years has been that for a 15-deg. rise in temperature of the incoming circulating water, during its passage through the condenser, it will be brought to within 15 deg. of the temperature corresponding to the vacuum. The proposition is frequently made to add only 10 deg. to the water and bring it to within 10 deg. of the vacuum. This is perfectly feasible, but we must see what this involves.

7 It means, first, that if we must carry away the heat from the steam by increasing the temperature of the circulating water 10 deg. instead of 15 deg., we must have 50 per cent more water with consequently larger and more expensive circulating plant and piping. With a 15-deg. rise to within 15 deg. of the vacuum temperature, the mean temperature difference between the steam and water side of the tubes will be 22½ deg. With a 10-deg. rise to within 10 deg. of the vacuum temperature, the difference will be only 15 deg. or, in the latter case 50 per cent more surface will be required.

8 Following the 28-in. vacuum line in Fig. 7, it will be noted that Mr. Bibbins has added practically 15 deg. to the condensing water and has given three curves—one for a good condenser with a temperature difference of 10 deg.; a very efficient condenser, 5 deg.; a perfect condeser, 0 deg.

9 Let us consider only the perfect or maximum-effect condenser with varying surface to produce the results named. For the zero-degree curve the mean difference between the steam and water side of the tubes will be 7½ deg; for the 5-deg. curve this becomes 12½ deg. and for the 10-deg. curve, 17½ deg. Or, if we should take the case

where we add but 10 deg. to the water, these three mean differences would become 5 deg., 10 deg., and 15 deg. respectively, so that the condenser for the zero-degree curve would have twice the surface required by the condenser on the 5-deg. curve and three times the surface required for the 10-deg. curve.

10 While there are several plants which report a circulating delivery temperature at approximately the temperature of the vacuum, it is evident that no plant should depend upon such a performance to obtain the economical results upon which the plant investment is based, as this would require absolutely perfect test conditions in every day operation; it would give no leeway at all and would result in too wide a variation in performance for a slight falling off in operating efficiency. Even a slight air leak would result in lowering the temperature in the vacuum space 5 deg., with a consequent loss in heat head and reduction in heat transference, owing to the presence of the air itself. These matters must be considered in addition to the question of cost.

11 Again, following the 28-in. vacuum line in Fig. 7 until it intercepts the 10-deg. curve, it will be found that it calls for water at 75 deg., the 5-deg. curve calls for 80 deg. and the zero curve for 85 deg. All these conditions assume that these results depend only upon the condenser, and if I understand the table correctly, call for the same quantity of steam and water, the temperature of the circulating water, it will be noted, being raised 15 deg. in each case. The author also assumes that the water is cooled to the temperature of the outside air.

12 Although I am sure that the author does not intend to convey the apparent meaning, the further statement is made that this calls for a fixed cooling tower performance; in other words, as I understand it, that the size of tower and the performance will be the same, to cool a given quantity of water through the same range in temperature, irrespective of the temperature of the air.

13 Let us follow this a little further, and in line with the general assumptions, assume for this purpose that the hot air leaves the tower at the temperature of the hot water and 100 per cent saturation. By reference to psychrometric tables it will be seen that each cubic foot of air at 70 deg. temperature and 70 per cent humidity, when increased to 85 deg. and 100 per cent, will take on 7.15 gr. of moisture, whereas a cubic foot increased from 47 deg. and 70 per cent to 62 deg. and 100 per cent, will take on only 3.575 gr. of moisture; that is, although the temperature is increased 15 deg. just the same, the air carries away

but one-half the moisture at the lower temperature, showing that twice the air capacity of tower efficiency will be required at the lower temperature. This is better understood when we consider that within the usual air temperature ranges, the moisture-carrying capacity of the air is doubled for each 22-deg. rise in temperature. To be brief and to avoid confusion, I have used the ordinary nomenclature, which is scientifically incorrect. We all understand that it is the space and not the air which is saturated, but this splitting of hairs would not affect the point under discussion.

14 I have purposely neglected the several minor considerations as they affect the question to a very small extent. For example, the volume of the air entering the tower at 70 deg. and 70 per cent humidity, and leaving at 85 deg. and 100 per cent humidity, is increased nearly 5½ per cent, due partly to the increased temperature and partly to the reduced pressure of the air itself, owing to the increased saturation and vapor present. It is well known that the cooling tower performs its work *principally* by the withdrawal of heat from the main body of water which provides the latent heat for the evaporation of a small portion of the water carried away in the form of vapor as increased humidity of the cooling air.

15 Temporarily omitting the *perfect* plant, let us consider an *average* operating plant in a location having air at 70 deg. and 70 per cent humidity. The usual cooling-tower turbine plant would carry a vacuum of 27 in. with water cooled from 100 deg. to 85 deg. If it is desired to cool this water from 90 deg. to 75 deg., this would permit of carrying a vacuum of 27¾ in. with the same amount of surface and water, but would require an increase in the quantity of air and of tower capacity of approximately 50 per cent. If it is desired to cool the water through only 10 deg. that is, from 85 deg. to 75 deg. and to bring the water within 10 deg. of the vacuum (28¼ in.) this would call for 50 per cent more water, 50 per cent more surface and over 100 per cent more air and cooling tower capacity than for the usual 27-in. vacuum plant.

16 There are hardly two plants which have quite the same determining factors. The determination as to the advisable vacuum and plant must be decided in each case, but there are few plants where the conditions would warrant the installation of a plant to produce the maximum vacuum under the most severe conditions.

17 With reference to the type of tower with fans in the stack, as shown in Fig. 2, the Worthington Company installed their first tower of this type with rope fan drive, in 1900, and recent reports indicate as

good results as when the tower was installed. As a general proposition, however, there are several questions to be considered in comparing this type. There is a saving in the number of fans over the arrangement with the fans below the tower filling, but the fan operates in the hot, highly saturated air, is more or less inaccessible and out of sight, and therefore will not receive the best of attention. It requires good installation and is more difficult to maintain in good condition owing to the fact that it is an exhauster. Any of us would prefer to install a pressure fan rather than an exhauster; the capacity of the fan in the stack must be somewhat larger for the reason that as neither the circulation or the surface efficiency is improved, the total volume of free air required is the same, this being handled at a less pressure and higher temperature and humidity.

18 Comparing the fan and natural-draft towers, there are few, if any, locations where high results are desired, where the natural-draft tower could be selected. A little calculating will convince any engineer that the draft is principally due to the wind velocity over the tower. Study of the meteorological tables will show that in most power centres, except in very few locations, the wind velocity is much greater in winter than in summer—just the opposite of our requirements. This is clearly demonstrated in the operation of any fan tower from the fan speeds permissible at different seasons. It must be remembered that with a tower of the same height the wind assistance is the same for either type of tower. There are many locations where a so-called combined tower can be used if the additional expense is warranted, but strictly speaking, the operation cannot be combined. It must be used either as a natural-draft tower or as a fan tower, but if the fan is operated at all, all the air must pass through it, whether the fan is located above or below the filling.

19 I do not see how there can be any induction in the tower shown in Fig. 14. The object of the tower is to get sufficient pressure below the filling to force through the requisite amount of air, but this pressure must be uniform in the entire space below the filling in order to obtain complete surface efficiency, and under such conditions air would leave rather than enter the tower through any additional openings to the outside air.

20 The Worthington Company make a so-called combined tower which permits of two water levels in the cold well. At the lower level the air enters through the fan at rest and below the lower plates of the tower shell above the water. At the higher level the lower plates are sealed and all the air enters through the fans, which can be operated

at the speed necessary to supply the additional pressure required by the low wind draft. This is also accomplished by the use of additional draft doors.

Prof. William D. Ennis. Will Mr. Bibbins explain in more detail the derivation of the curves in Fig. 7? The tower must provide cooling sufficient to absorb the heat liberated with the exhaust steam, viz., 939 B.t.u. per pound. The amount of cooling in each case would then be 939 divided by the weight of circulating water per pound of steam. On this basis, the maximum temperatures of entrant air agree closely with the curves at 27-in. and 28-in. vacuum, but are about 1 deg. higher than the curves indicate at 29 in., and 2 deg. or 3 deg. higher at 26 in. The curves should apparently be more nearly straight.

2 The paper gives unusually complete and valuable data on many phases of cooling tower operation, but it is to be regretted that the matter of loss of water has not been dealt with in more detail. This is perhaps the most vital question. Manufacturers are sometimes asked to guarantee a limit of loss, but it would be just as logical to ask for a guarantee as to the value of π. A rough estimate often offered is that the loss will not exceed the amount of boiler feed water.

3 Mr. Bibbins gives data from three plants: that at Duquesne, in which the makeup water was from 10 to 20 per cent; the Potosina plant, in which the loss of vapor by windage was occasionally as much as 10 per cent of the volume (of water?) passing through the tower; and the Detroit natural-draft plant, in which the vaporization loss was 2 per cent of the water passing through; practically equal to the weight of boiler feed. The average cooling per hour was $(293{,}530 + 5910.6) \times 16.23 = 4{,}860{,}018$ B.t.u. Each pound of water vaporized, if we neglect the cooling effect of the air, must then have absorbed $\frac{4{,}860{,}018}{5970} = 816$ B.t.u. This is the nearest to a reasonable result I have ever seen in a cooling-tower test.

4 Usually, and this apparently applies to the two other cases cited by Mr. Bibbins, the loss of water is far greater than theory indicates as necessary. The cooling of the water is accomplished by (*a*) the absorption of heat by the air and (*b*) the evaporation of a portion of the water. When the minimum temperature of the air equals or exceeds the maximum temperature of the water, the first effect becomes zero. When the air is initially saturated, the second effect becomes zero, except as the air is heated during its passage. Under

the limiting condition at which there is no direct transfer of heat to the air, the necessary volume of air is increased, and the loss of water does all of the cooling; but the proportion lost need not exceed, in theory, the quotient of the range of cooling by the heat of vaporization, and the use of screens unables us even to reclaim some of the otherwise lost vapor. Why is it that almost invariably the make-up water greatly exceeds the amount thus computed as necessary? It is inferred from Par. 34 that Mr. Bibbins has considered this question of cooling by evaporation, in which case some exposition would be desirable.

Henry E. Longwell. Very early in 1884, under the direction of John C. Dean, of Dean Brothers Steam Pump Works, I made drawings for a cooler that was built for the Kane Milling Co., Kane, Ill. I am told that it was the first one erected in the United States, and it is, at any rate, a well-authenticated case of a very early installation. The plant was operated for only two years, being then destroyed by fire, but so far as I can remember the installation performed in a very creditable manner, especially considering the primitive state of the art at that time.

2 There are probably many engineers who will take issue with the author if he means that the cooling tower field is yet comparatively unexplored. For ten years or more the cooling tower has been on a strictly scientific basis. Its design and construction constitute a branch of engineering that is just as distinct and as well developed as any of those which deal with other specialties such as gas engines, steam turbines and the like. When we consider that one builder alone has constructed about 2000 cooling towers which in the aggregate are capable of cooling condensing water for about 3,000,000 horsepower, we must admit that this device has progressed a long way beyond the rudimentary stage.

3 It is not excessive cost or lack of knowledge that has restricted the use of cooling towers in the United States. It is because nature has been so good to us that the conditions in which cooling towers are desirable or necessary are comparatively rarer than in the less favored and more congested European countries, where these devices have reached the highest state of development.

4 I regret that the author has not presented in exactly the same form the two tests of the cooling tower described. In Table 4 is given a complete log of the principal observations made at approximately hourly intervals; in Table 5 we have only the average of all the

observations made over a period of 24 hours. The two tests were made under such widely different conditions that they afford no proof as to whether the performance of the tower was any better or even as good with its full complement of cooling surface, as it was with only three-fifths of it. During the test with only three-fifths of the cooling surface installed, the average load was nearly 80 per cent greater, and the average quantity of water circulated per hour was nearly 35 per cent greater than on the test with all of the surface installed.

5 Referring to Fig. 11, the indications are that the added cooling surface served no useful purpose. Indeed if the diagram means anything at all, it means that for the same temperature head the product of the heat dissipated per square foot of surface per hour multiplied by the proportion of the cooling surface installed, is practically a constant; also, that for equal temperature heads, the number of degrees cooling is practically the same.

6 In Fig. 12 in which temperature head is plotted against degrees of cooling, the lines corresponding to 3/5 surface and 5/5 surface, coincide so nearly that one could hardly say that they depart from each other by more than the limit of the normal error of observation.

7 Fig. 13 at first sight seems to indicate that at hot-well temperatures below 120 deg. the cooling was considerably greater with 5/5 than with only 3/5. But we know that on the test with only 3/5 of the surface, the amount of water circulated was very much greater than with 5/5 surface. Comparisons of this sort are misleading unless the quantity of water circulated per hour and the temperature of the incoming air are the same in both cases.

8 The inconsistency of the curves in Fig. 13 will become apparent if we extend the straight line curve for 3/5 surface until it cuts the line of zero cooling. This will indicate that at a hot-well temperature of a little above 85 deg. the water would not be cooled at all, although we know from Table 4 that the temperature of the incoming air was at no time higher than 35 deg. The inference would be that water entering the tower at a temperature below 85 degrees would be warmed by coming in contact with air at or near the temperature at which water freezes.

9 The indications are that the tower is too small for the work, and that its performance is limited, not by the amount of cooling surface, but by the weight of air that can pass through it in a given time. After all, it is the air that carries off the heat, and the quantity of air passing through the tower is just as important a factor as is the area of the cooling surface.

10 The tower described occupies 200 square feet of floor space, and is rated at 900 h.p. Assuming 15 lb. of steam per h.p. hour, the tower would have to cool sufficient water to condense 13.500 lb. of steam hourly. A natural draft tower designed by one of the most experienced builders of this class of apparatus, would for this same duty occupy a space about 29 by 24 ft., or nearly 3½ times as great as that occupied by the towers described. It would also be from 7 to 10 ft. higher, which would give a more powerful draft.

11 Referring again to Fig. 12, it will be seen that the temperature of the water leaving the natural-draft tower is from 40 to 70 deg. above that of the incoming air. On this same diagram are curves which purport to show the performance of the forced-draft tower briefly referred to in Table 3. It would appear from these curves that the forced-draft tower under favorable weather conditions cools the water to within 3 or 4 deg. of the atmospheric temperature. Under unfavorable weather conditions it appears to cool the water to within 15 to 35 deg. of the temperature of the atmosphere.

12 The cost of the forced-draft tower is given as $2.60 per h.p. as against $1.50 for the natural-draft tower. However, if the comparative results as shown in the diagram Fig. 12 are dependable, it would appear that the forced-draft tower was well worth the additional cost, and a little bit more.

13 In Fig. 7, the author purports to show the maximum temperature of inlet air permissible for various vacuums. This diagram really shows the maximum temperature of cooling water to produce a given vacuum on the assumption that we limit the number of pounds of cooling water per pound of steam condensed, to the arbitrary figures set down in the lower right-hand corner of the diagram. The temperature of the atmosphere is not necessarily the limiting temperature to which the water may be cooled. It is well known that with low humidities, cooling towers may reduce the temperature of the water to several degrees below that of the atmosphere. And there is no law of nature that stipulates that we may circulate no more or less than 100 lb. of condensing water per pound of steam to produce a 28 in. vacuum, or 60, 40 and 30 lb. per pound of steam to produce respectively vacuums of 27, 26, and 25 in.

14 Fig. 15 is doubtless interesting, but as no reference to its usefulness appears in the paper it is difficult to see wherein it is pertinent.

15 I would point out that the diagram Fig. 1 shows that on two days in June 1906 the *average* temperature exceeded 90 deg. According to Table 1 on the following page there was not a single day during

that month on which the *maximum* temperature reached 90 deg., to say nothing of the average. If there were 10 days in the month of June 1906 on which the temperature exceeded 75 deg., it is difficult to see why there must not have been at least as many days on which it exceeded 70 deg. The quantities set down in the columns headed "Average for Month" require some explanation to make them intelligible.

16 The theory of cooling towers is simple, and any one who has a reasonable acquaintance with that branch of natural science which deals with heat, may easily know it a little or even very well. As far as the theory itself is concerned it would be hard to improve on the clear, concise and generally masterly presentation of the subject by F. J. Weiss, inventor of the well-known Weiss condenser, which appeared in a book entitled "Kondensation," published in Germany about ten years ago. But as in all branches of engineering, the coefficients by which theory is reduced to practice, are the property of the few, who by special application and practical experience have come to know the subject profoundly.

Barton H. Coffey.[1] The advent of the turbine with the high cost of fuel in steam plants and the increasing cost of water for cooling purposes in urban installations of refrigeratin apparatus, are making the cooling tower a necessary means of economy.

2 As the author remarks, the literature upon the subject is scanty; in fact, with the exception of C. O. Schmitt's paper before the South African Association of Engineers in 1907, there is scarcely anything extant that I know of, worthy of the name.

3 I do not wholly agree with Mr. Bibbins' presentation of the meteorological conditions to be met by cooling towers, as given in Fig. 1 and Table 1. The comparison of average humidity and temperature, as given by the weather bureau, is a little misleading, as the humidity observations are made at 8 a. m. and 8 p.m. only. In lieu of hourly humidity measurements, I think it better to take the average aqueous pressure at 8 a.m. and 8 p.m., as it is known that this quantity changes slowly, and from this the hourly humidities can be calculated. It will then be found, of course, that as the temperatures advance toward midday, the humidity falls, thus tending to maintain average thermal conditions with respect to cooling towers and explaining the approximately uniform results actually obtained. The mean aqueous pressure for July, covering a number of years, work out about as follows:

[1]With Edwin Burhorn, 71 Wall Street, New York.

Table 1 Mean Aqueous Pressure

	Actual Aqueous Pressure
Boston, Mass.	0.542 in. mercury
Philadelphia, Pa	0.614 " "
Salt Lake City, Utah	0.296 " "
St. Louis, Mo	0.648 " "

At St. Louis, therefore, where the mean maximum temperature for July is 88 deg., the relative humidity would be 49 per cent against a mean humidity of 66.1 per cent, as given by the tables, which is distinctly a more favorable condition for cooling towers.

4 While on meteorology, I would like to call attention to the statement in Par. 15*b*, that the tray or atmospheric type of tower cools only by means of "transverse air currents from the side", the obvious deduction being, that without wind this type of tower fails. As a fact, in a dead calm the efficiency of all forms of tower falls off, but this condition is of small practical account, as in the interior region the percentage of calm rarely exceeds 2 per cent of the month and on the seaboard is practically unknown. However, in a dead calm the towers still continue to work, due to an ascending column of warm air and aqueous vapor over the tower and a corresponding horizontal inflow of cool dry air. This condition must exist, otherwise the entire space surrounding any tower would become filled with warm saturated air and all cooling would cease. In a forced-draft tower for example, the fan would be simply circulating air having no capacity for absorbing heat. Apropos of this, I have records from an atmospheric tower on refrigerating work for the entire month of September 1907, taken with recording thermometers, in which the cooling water from the tower was maintained at an average of 75 deg., never exceeding 80 deg., with a cooling range of about 10 deg.

5 In Par. 13*b*, among the elements of design, Mr. Bibbins advises "Avoid free falling water. It should be distrubuted so as to descend clinging to some form of wetted surface." I would like to know the basis for this statement, as probably by far the largest number of towers in use throughout the world employ the principle of finely divided falling water, as, for instance, the various forms of atmospheric and chimney towers in Europe, South Africa and this country.

6 As 75 to 85 per cent of the cooling is due to evaporation, which can take place only at the surface in contact with the air, the form of cooling surface is of great importance. In a cooling tower with free-falling water, the cooling surfaces consist of the hurdles or decks and the exposed surface of the falling water. Experiments show the

weight of a drop of water to be about three-fourths of a grain, the diameter of the corresponding sphere being 0.178 in. A gallon of water properly distributed will therefore expose about 54 sq. ft. of surface. If we know the flow per second and the time of fall in seconds, properly corrected for atmospheric retardation, we can calculate the exposed surface in the water, which, added to the fixed wetted surface, gives the total cooling surface in the tower. The efficiency of the surface in the falling water is greater than the fixed surface, due to the greater velocity of the air relative to the water surface, due to the motion of the drops.

7 The question of type of surface, in my opinion, is one of expediency to be determined by the conditions of operation. Fixed surface is undoubtedly more compact and when skillfully designed opposes less resistance to air currents. On the other hand, it involves weight, greater difficulties in distribution, and where oil is present in cooling water, it becomes coated, the capilarity is destroyed and the water film is reduced to streams, thus greatly lessening the water surface exposed.

8 If the atmospheric form of tower is to be employed, it is hard to conceive of any form of surface, save drops, that would be exposed to the wind from any direction; and where space is available for sufficient surface, the temperature reduction called for can always be attained.

9 In a test by the speaker of an atmospheric tower circulating 440 gal. per min., with air at 93 deg. and humidity 34 per cent, the water was cooled from 80 deg. to 74 deg., or within 3 deg. of the wet bulb, which is the limit of atmospheric cooling.

10 With reference to Mr. Bibbins' remarks on the effect of temperature range on the size of the tower, I beg to submit a few figures on the volume of air required at 80 deg. and 80 per cent humidity to absorb 1,000 B.t.u. when the air can be heated to the following final temperatures and saturated:

TABLE 2

Class of Work	Final Temp. Air	Cubic Feet
Refrigeration	88 deg	985
Steam Condensing 27 in. vac.	100 "	429
Steam Condensing 26 in. vac.	110 "	267

This shows the enormously increased quantities of air required as the lower ranges of cooling are approached, and also shows the particular advantage of the atmospheric tower for refrigeration work, in saving the power necessary to handle this large volume of air. As an example:

11 With air at 80 deg. and 80 per cent humidity, to cool 600 gal. of water per min. to 80 deg., would require about 70,000 cu. ft. of air per min., requiring about 17 brake horsepower in a fan tower. An atmospheric tower of like capacity, having 960 sq. ft. wind exposure, would receive 248,000 cu. ft. of air per min. at a velocity of 4 miles per hour. In steam condensing, with a limited space the forced-draft tower is, of course, the only available type.

Carl George de Laval. The author states that the present high prices constitute the greatest obstacle to the use of cooling towers, and, further appears to give the impression that the cooling tower is a makeshift and not a permanent apparatus.

2 There are three classes of towers, forced-draft, natural-draft and a combination of both, the last-named being used either way depending on the season of the year. The selection of the type should depend on climatic conditions, cost, etc., a dry climate being best suited for a cooling tower.

3 The author states that the costs range from $4.80 to $6.93 per kw., which appear to be slightly higher than market prices, the reason perhaps being that the author had imposed severe conditions when asking for bids on cooling towers, thereby increasing the costs.

4 Let us assume a plant of 1,000-kw., consuming 19,000 lb. of steam per hr., basing the condenser performance upon the ordinary 10-deg. difference in a counter-current jet condenser, and upon a 27 in. vacuum, with air at 70 deg., and 70 per cent relative humidity. A cooling tower with interlocking pipe filling can be built approximately 19 ft. by 35 ft., fitted complete with fans, for about $5 per kw., and a wood-filled tower about 21 ft. by 35 ft, for about $4.50 per kw.

5 The author is correct in stating that installations are not being sufficiently studied, and this, no doubt, is the principal cause for the failure of cooling towers and has prevented their more general adoption. It is not sufficient merely to obtain information as to maximum load, steam consumption, maximum temperature and humidity, but it is necessary to know whether these maximum load conditions must be met at the conditions of maximum temperatures and humidity, and if so, for how long a time.

6 Let us assume that bids are asked for a cooling tower for 8,000 kw., the conditions named being an air temperature of 75 deg. and 75 per cent humidity, 27 in. vacuum, no time being stated when this load of 8000 kw. is likely to occur, and what its duration is. The real facts may be that this load comes in winter only, and that in

summer probably not over 5000 kw. would be required during the evenings, while the summer mid-day load might not be over 2000 or 3000 kw. Under such conditions a tower calculated for a 5000-kw. summer load would be ample for an 8000-kw. winter load, and if the installation was made on the basis of 8000 kw. the year round, the cooling tower would be too large and expensive, and the cost per kilowatt of maximum load would be too great.

7 The maximum mid-day temperature and humidities likewise should not be the basis of consideration with maximum loads, as the electric lighting plant maximum during summer should instead be based upon 8 p.m. temperature and humidities. One sometimes sees the requirement to handle maximum loads at an atmospheric condition of 90 deg. and 80 per cent relative humidity—a condition that may never be reached in the particular locality where the tower is to be installed.

8 Most of the towers described by the author appear to be home-made or makeshift towers, for instance, the tower shown in Fig. 6, and, installed at Butte, Mont., having a cross-board filling and a wooden stack for natural draft. The design is such that it will lose considerable of its efficiency as it continues in service, and the boards, as well as the upper stack, will warp, admitting cold air above the filling and tending to kill the draft upon which such a tower depends for its efficiency. The warping of boards will also cause leakage through the sides of the tower, the leakage being carried by any strong breeze, and thrown against surrounding buildings and territory, where during winter it may freeze into a heavy mass.

9 Referring to preceding discussion on the design of towers for maximum atmospheric conditions, one will note in the temperature ranges in Table 2, for the Butte tower, that the atmosphere was over 80 deg. during less than 3 per cent of the total time of the year, so that such conditions can hardly be used as a basis for calculation. Atmospheric conditions at Pittsburg during the four months from May 15 to September 15 average approximately 70 deg, and 70 per cent, which appears to be about a standard basis for cooling towers.

10 Par. 9 refers to the use of cooling towers for handling jacket water of gas engines, the temperatures being about the same as those encountered in ice plants, and higher than in the case of steam condensation. Several installations show this temperature to be from 156 deg. to 111 deg., and 130 deg. to 80 deg.

11 Par. 10 and Par. 11 state that the difference between the theoretical steam temperature and the temperature of the circulating

water varies from 10 deg. to 50 deg. The usual jet condensers and surface condensers give about 15 deg., and cooling towers for reciprocating engines are usually based on a 24-in. vacuum, with circulating water cooled from 125 deg. to 100 deg. and an air temperature of 70 deg. and 70 per cent relative humidity. Counter-current condensers give about 10 deg. difference, the circulating water being handled under the same conditions of vacuum, with a temperature range from 130 deg, to 105 deg., instead of from 125 deg. to 100 deg., which of course gives an easier condition for the cooling tower.

12 It is a well-known fact that an efficient condenser must be installed in order to get good work from a cooling tower, it being an advantage to the tower to have the temperature of the hot water and the cold water as high as possible. For instance, taking examples of the two conditions, both 1000-kw plants consuming 19,000 lb. of steam per hr., at 24-in. vacuum, and an air temperature of 70 deg. and 70 per cent relative humidity, one plant being based on a 40-deg. difference between the exhaust steam and the outlet circulating water, which requires the water to be cooled from 100 deg. to 75 deg.; the other plant being based on a 10-deg. difference between the steam and the water, the water being cooled from 130 deg. to 105 deg. In the former case, for the same load, vacuum and air temperature, we require an interlocking pipe-filled tower, 22½ ft. in diameter by 35 ft. high, having four 96 in. fans; whereas in the latter case with only a 10-deg. difference we can do the same work with the tower 13 ft., 6 in. in diameter by 35 ft. high, having one 120 in. fan. The efficiency of the condenser therefore makes a very decided difference in the size of cooling tower.

13 Under *c* in Par. 13, the author apparently refers principally to towers with wood sides, having a wood structure within the outside boarding. It is very important that the filling must come close to the side of the tower. Particular care should be taken in erecting towers to see that pipes are first laid around the outside edge as closely to it as possible; otherwise, there will be a short circuit of cold air around the side of the tower and a loss of efficiency. This condition, while bad enough in the forced-draft tower, is much worse in towers of natural-draft type, because this air will seriously reduce the draft by mixing with and cooling above the filling the heated air upon which the draft depends.

14 As to height of working section, it is true, as the author states, that the height is important, and the distance of the elevation of the water should be kept as low as possible. A pipe-filled tower is

13 ft. 4 in. deep with a drop at the bottom of from 6 ft. to 11 ft; according to the size of the tower. With a distributor operating head of 5 ft., this gives the largest towers a maximum pumping head, plus friction in the piping, of 29 ft. 4 in. against approximately 38 ft. as required in the experimental natural-draft tower at Detroit, shown in Fig. 9. The horsepower necessary to pump the water the additional 8 ft. 8 in. in height will offset the usual fan horsepowers, making a natural draft tower of this type more expensive to operate than a fan-draft tower.

15 As to the mat of wood swelling and being thrown out of place, I would state that towers have been built with a cross-board wood filling, and four of these have been in satisfactory operation since 1904. In these towers were used 2 in. by 2 in. verticals at intervals through the filling, with the boards nailed so as to hold the filling in place and prevent distortion or formation of large open gaps through warping of the filling.

16 The cooling towers illustrated in Fig. 3, are furnished with perforated pans and have free-falling water, the sides being screened. This tower depends for its efficiency upon a cross breeze and is very inefficient in still air as the air cannot rise within the tower on account of the pans. A strong breeze will blow most of the water out through the sides of the cooling tower, in spite of the screen. The tower shown in Fig. 4 occupies considerable space, and also requires additional space in the immediate vicinity because of loss of water through windage. The tower illustrated in Fig. 5 is evidently much less efficient than that in Fig. 4, because of the large amount of free-falling water. The free-falling or splashing of water is a very inefficient method of cooling. Water for proper cooling should always be brought down in contact with a surface so that it will descend slowly and thus have close and intimate contact with surrounding air.

17 In Par. 26, the author gives the total cost of the Detroit tower, erected complete and including filling, distributing pipes, foundations, etc., at \$1350. It appears that the steel work, if made of at least No. 10 gauge, would weigh approximately 20,000 lb., which at 6½ cents per pound, which is about as low a rate as mentioned, would require an expenditure of \$1300 for steel work alone. The lath filling and the work of assembling and installing this tower, would cost about \$400; the timber supports, distributing piping, etc., about \$250; concrete foundations an additional \$250, or a total cost of \$2200. Assuming a load of 1000 hp. with 19,000 lb. of steam per hour, vacuum 24 in., with a temperature difference of 10 deg., the

circulating water being cooled from 130 deg. to 105 deg., air at 70 deg. and 70 per cent humidity, a pipe-filled cooling tower of the fan type, measuring 13 ft. 6 in. by 35 ft. could be installed for about $2500.

18 The results of the test given in Table 5, with atmospheric temperatures of from 18½ deg. to 30 deg., are not complete for a natural-draft tower, as such towers fall off in efficiency very rapidly when the air temperature is raised. The results at temperatures from 70 to 80 deg., would not be so favorable.

19 In Par. 30, the condition of scale covering the wooden filling would be experienced in any tower, and is usually encountered where well water is used to make up in cooling towers for refrigerating plants. The scale forms a protecting coating in a pipe tower and prevents possible rusting of the pipe filling.

20 In Par. 32, the author refers to possible advantages of a slotted pipe as compared with spouts on a distributor arm, in regard to clogging. The spouts used by some first-class designers are 1 in. in diameter and are consequently much less liable to clog than are pipes having a ⅛ in. slot in the top.

21 In Par. 15, the author refers to the use of sprays over a pond. This seems a very simple apparatus, but it must be realized that the sprays require from 15 to 20 lb. pressure at the nozzle and so consume more power than required for circulation through a cooling tower of the fan type, and in most cases as much power as is required both for the circulating of the water and for the driving of the fan.

22 The arrangement of cascade or cooling sprays on a roof as described by the author is not new. The installation was in use by J. H. Stut of San Francisco, previous to 1892, being placed upon the roof of a factory. Galvanized troughs, 5 ft. wide were arranged in tiers on a slight incline so that the water traveled back and forth a distance of about 2,000 ft. before being returned to the condenser. An arrangement of falling from one trough to another, these troughs being spread out upon a roof, was used at the old Budweiser Brewery in Brooklyn previous to 1890. The sprays and roof troughs are alike open to the objection that if there is a strong breeze the water is carried all over the surrounding neighborhood and if there is no breeze, a heavy fog quickly collects at the point of spray and thus greatly reduces the amount of cooling.

23 Referring to various types of filling illustrated in Figs. 8*a* to 8*c*, Fig. 8*a* offers too serious an obstruction to the draft within the tower, closing more than 40 per cent of the space necessary for verti-

cal circulation of air, as against 3 per cent covered by interlocking pipe-filling or 25 per cent by wood filling. The cascades as illustrated must fall as shown in the sketch in order to operate efficiently, that is, the water must strike the pans on the next lower section of the filling, but this they will do only if the amount of water supplied is practically constant, otherwise it is liable to spill over several rows of filling, and result in quick descent and consequent loss of efficiency.

24 The filling illustrated in Fig. 8*b* is that used by Henry W. Bulkley, and depends upon a cross steam of air, as in the tower shown in Fig. 3. It is open to exactly the same objection as the latter tower.

25 The filling 8*c* will cause large quantities of free-falling water between the several courses and will result in inefficient operation. The filling 8*e*′, a wooden cross-board type, is apparently good. It requires additional expense in placing, but evidently will save something in fan horsepower. The filling 8*d* offers a bad obstruction to the draft on account of deflecting the air alternately to the right and left. The water also will evidently flow down the top side of the board, whereas the air impinges most strongly against the lower side of the board.

26 The filling 8*b* is the same as 8*b*′ and is good. The filling 8*g* is open to the objection of having no redistribution,—the water distributed at the top, however unequal it may be, must remain unequal from top to bottom. The filling 8*f* has one redistribution at the center. Otherwise it is open to the same objection as 8*g*.

27 In Par. 23, and also in the footnote, it is stated that ball bearings are difficult to keep in good condition. Ball bearings are not used in modern towers, a floating water-step bearing being used instead.

28 Referring to Par. 41 and Par. 42, a combination type tower may run with natural draft about eight months during the year. At a plant in Newark, N. J., a combination type tower with side doors operates on an 800-kw. load nine months of the year with natural draft, and requires 25 hp. during the remaining three months of the year.

29 As to Par. 46, efficient condensers are more badly needed than efficient cooling towers. Cooling towers have reached as high an efficiency as can be expected, but most plants now operating with direct jet condensers delivering into the towers, could obtain much higher vacuum or handle greater loads at the present vacuum, if condensers of the counter-current jet type, or the more efficient baffled-surface condensers were substituted in place of the condensers originally furnished.

30 As to Par. 48, the temperatures are practically the same as in ice plants. In order to get the temperature head mentioned, it is more economical to circulate the water for the ice plant first through the ammonia condenser and then through the steam condenser delivering to the cooling tower, than to have two towers handling separately the water of the ammonia condenser and that of the steam condenser.

31 The open wooden towers referred to in Par. 50 are not restricted to points of low humidity; but as already mentioned, they require much open ground, not only on account of their size, but also for wind effect, and that surrounding buildings may not be drenched with water blown from the tower.

32 As to Par. 51, the tower best adapted to natural-draft work is the one which offers the least resistance to the ascending current of air. In Par. 52, no temperatures are given to substantiate the statement of heat dissipation by lath mat construction.

33 As to Par. 53, one cannot endorse the fan booster or induction type when combination towers can be made that will give better results and that are surely preferable for overload conditions.

34 The largest number of towers in this country are of the forced-draft type, while European practice tends towards natural-draft towers. It is thus apparent that there can be no standard of type or size, because of difference in climates; each installation must be considered as a separate problem.

E. D. Dreyfus. In Par. 10, Mr. Bibbins says, "But in practice from 10 to 15 deg. difference exists, depending upon the type of condenser and the volumetric ratio of water to steam." I wish to supplement this by adding that it does not depend altogether on the volumetric ratio. Another important factor is the effectiveness of air removal. Those who have had considerable experience in condenser work find that the more effectively the air is withdrawn, the nearer the theoretical vacuum is reached. By this means it is possible to operate with a diminished volumetric ratio as the temperature rise is increased.

2 Exception is to be taken to Mr. Foran's remark that perfect condenser operation entails much greater experience, which might be implied as generally applicable. This is true only of surface condensers. In cooling tower practice, the conditions are extremely favorable to the use of the more simple jet type. The more efficiently this latter type is operated, that is, the nearer the discharge water

is brought to the temperature of the exhaust steam, the smaller is the volume of water necessary, since volume and temperature rise are component factors of the B.t.u. extraction. Therefore, with less volume of water handled, the size of the condenser may be reduced and consequently furnished at a smaller cost.

3 A remark made by the author in presenting the paper, that an inefficient condenser and an efficient cooling tower go hand in hand, bears further explanation, although the statement was modified somewhat subsequently. With an inefficient condenser, the vacuum is not likely to be very good, and therefore, with the higher temperature prevailing in the condenser, the water might pass to the tower at a higher temperature, making it easier for the latter apparatus to perform its work. On the other hand, the statements might be applied with equal, if not greater, force to efficient condensers which are able, for the same condensation, to create higher vacua, besides heating the discharge water up to the same final temperature head as the inefficient type, there being little or no terminal difference in an efficient design at its normal capacity. Moreover, considering the benefit accruing to the prime mover, a smaller volume of water may be used and worked at the same temperature as in the inefficient type of condenser, thus increasing the possibility of the tower. I would qualify the above statement to the extent that it deals with a comparison of condensers designed for the same vacuum, and evidently would not hold for a case where a very poor vacuum was admissible.

4 It might be well to state here that a near approach to the theoretical vacuum is not an impossible condition in actual operation. This implies, of course, that the character of the condenser design—the counter-current type with an efficient air pump—fulfills the requirements. In a test which I conducted last Fall on a 1000-kw. low-pressure turbine equipped with a counter-current jet condenser, the following results were obtained: At three-fourths load with 83 deg. injection water, a vacuum of 28.20 in. (30 in. barometer) was maintained, and the water left the condenser at a temperature of 96.8 deg. The temperature corresponding to the vacuum was 97.6 deg., giving practically one degree terminal difference.

5 I have observed that temperatures of the water leaving the tower were several degrees colder than the atmospheric temperature in warm weather, the difference being as much as ten degrees at times.

6 With the increasing recognition the cooling tower is receiving, it would be desirable to have the Society define a standard basis of

measuring the efficiency of the apparatus. There is a conspicuous lack of harmony of opinions as to what constitutes the governing characteristics of tower performance.

T. C. McBride In the earlier parts of the paper the author would lead us to believe that cooling towers have not received the scientific attention warranted. Reference to the literature on this subject and the work that is being done hardly confirms this fact. A considerable number of manufacturers have for some years past been supplying cooling towers designed on scientific lines, and the proposals submitted by them, particularly on fan-type towers, are intelligently framed and leave no points whatever open to guess work.

2 The paper very properly calls attention to the intimate relationship of condenser efficiency to cooling tower performance, but in doing so is extremely unfair to the condenser—in fact, in speaking of different types of air pump, the author almost leads us to believe that some are so superior to others that the vacuum they create is of a superior kind compared to that created by other air pumps.

3 Condenser engineers now agree that the efficiency of condensers, with regard to the comparison of discharge-water temperature with theoretical vacuum temperature, is as much a question of the average temperature of the vapor in the condenser as its design. The average temperature of the condenser is necessarily determined by the amount of air present therein, and is a direct function of the ratio of the air-removing capacity of the air pump and the volume of air reaching the condenser with the steam. The merit of the air pump cannot therefore be determined either from the vacuum obtained or from the relation of the discharge-water temperature to the theoretical vacuum temperature, but is wholly a question of the capacity of the air pump to handle air at the least expenditure for power, maintenance, interest on first cost and depreciation.

4 It is true that the question of condenser efficiency and air-pump efficiency is somewhat involved with that feature of condenser design having to do with the reduction of air-pump suction temperature, but as all condenser designs should take care of this feature it may be eliminated from the comparison of types of condensers or types of air pumps. It is conceded that the author's division of condensers and air pumps into good, indifferent and bad classes, in accordance with the vacuum and discharge-water temperature obtained, follows lines which have been generally accepted in the past; but a view from an engineering standpoint must consider the

impurities in the steam in the shape of air and non-condensable vapors, before judging any particular type of condenser or air pump.

The Author is exceedingly grateful for the interest shown in the paper and the practical nature of the discussion, which has served to clear up several ambiguities and to extend the subject into channels of inquiry representative of everyday commercial problems.

2 Mr. Ennis deprecates the loss by windage of considerable volumes of circulating water, in excess of that supplied by condensed steam. Theoretically, without windage loss, there should be practically no make-up water required, as an exact thermal balance has been established. But this loss does occur in both forced-draft and open tray type towers, and often to a serious extent. However this is simply a point in favor of the closed natural-draft type of tower, in which the velocities are reasonably low and hence small tendency exists to abstract water from the cycle.

3 The high loss in the Duquesne Lighting Co. Plant, it should be explained, is not due to windage. The hot jacket water can only be partially cooled, consequently enough must be thrown away to lower the temperature by the addition of fresh cold water. The loss at Potosina, however, was entirely due to windage.

4 The curves in Fig. 7 may very possibly be slightly in error, as they were necessarily based upon arbitrary assumptions—hence no attempt was made at absolute accuracy.

5 Mr. Foran evidently has had in mind the surface condenser in discussing possible and probable temperature differentials, whereas the author has referred more particularly to the barometric or jet types, especially in Fig. 7. This should have been stated more clearly in the paper. Generally speaking, it is possible with the jet type to work with much lower differentials than with the surface type. Mr. Foran's deductions regarding the extent of surface required to meet special conditions are therefore entirely proper. This very difficulty which is experienced with surface condensers in meeting the conditions imposed by the best cooling tower practice, only emphasizes in the author's mind the inherent advantages of the jet types.

6 The term "fixed cooling tower performance" could not apply to the construction of the curves in Fig. 7, as it is here used in the sense of efficiency rather than size. The use of "performance" here was in reference to relative cooling effect (deg. fahr.)—not capacity for absorbing heat—for the sake of eliminating another variable in the construction of Fig. 7. The size or capacity for a given con-

dition is simply a function of a heat quantity (B.t.u.) absorbed from the exhaust steam. For a given type of surface and draft velocity, the rate of absorption is fairly constant—a parallel to the constant rate of heat transmission through the tubes, as cited by Mr. Foran.

7 In reference to the Detroit tests, Table V, it should be noted that the condensing plant was not well adapted to the work in view, being an equipment temporarily retained in service from an old plant, too limited in surface and without means of operating air and water pumps individually, as required for economical working. The poor results from this particular plant were therefore distinctly attributable to the temporary nature of the installation, and not to an inherent fault in the type itself, as might be gathered from the reports.

8 In his closing remarks, Mr. Foran seems to confine the use of "natural-draft tower" to the open tray type. It is quite true that this has no application where large capacities or the highest efficiency are necessary. The closed chimney type is not dependent to any extent upon lateral wind velocity, and may be designed to economize space effectively.

9 The point raised by Mr. Dreyfus in regard to the effect of low temperature differentials is well taken. The author's observation that poor vacuum and good cooling go hand in hand applies to a given equipment, but the highly efficient condenser with low differential of course finds the most direct application.

10 The author did not observe or infer that the cooling tower field remains comparatively unexplored, but that certain conditions have tended to render the subject a closed book. This is not the case with engines, turbines, boilers, condensers, etc., so the fact that this condition obtains with cooling towers is not readily justifiable.

11 The two series of tests could not be presented in identical form, as the data were not available in such form. However, the curves, Figs. 11, 12 and 13, were drawn up to facilitate comparison. The first test covered day and peak loads only; the second, the entire 24 hours,—hence a low average load, as Mr. Longwell observes. Because the tower shows a low rate of heat dissipation with the entire surface installed, it should not be inferred that the actual work done was proportionately lower. Considering abscissae (B.t.u.) as equivalent to load (kw.) it must be apparent that for the same load a much higher cooling effect was obtained with the cooling surface complete.

12 For equal temperature heads, the cooling is bound to be the same except when the "lost head" differs, as it does slightly in Fig. 12. This opens up an extremely interesting line of inquiry—a survey

of rates of heat dissipation and humidity in each successive zone of the tower. Which part of the tower does the most work? Assuming air to be discharged exactly saturated at the temperature of exit, what spacing of mats is correct to produce a proper gradation of humidity from, say 70 per cent at entrance to 100 per cent at exit?

13 Regarding the inconsistency of Fig. 13, Mr. Longwell has forgotten to reckon the "lost head" shown in Fig. 12—approximately 40 deg. There is thus a very small discrepancy. However, it is hardly safe to interpolate in such a case. It is already pointed out in the paper that the tower is working at a disadvantage, owing to the extremely poor condenser performance, that imposes an extra burden on the prime mover as well.

14 The circulating water ratios adopted as a basis of the curves in Fig. 7, were so adopted to approximate average practice, otherwise a "family" of curves would replace each single curve shown.

15 Mr. Coffey favors the use of vapor pressure in lieu of relative humidity. The author entirely agrees to this method as more scientific. However, absolute humidity expressed in grams per cubic feet perhaps has a more direct bearing on cooling tower work.

16 The suggestion "to avoid free falling water" should have been amplified in the paper, and Mr. Coffey justly directs attention to it. Compactness or maximum duty for a given size is so essential in restricted locations that the atmospheric type is handicapped, if not debarred, which he himself recognizes in the closing sentence. The paper is directed entirely along these lines of maximum duty, and especially toward the development of the natural-draft type.

17 Mr. de Laval advances the argument that a tower should not have to be designed, rated and purchased *entirely* on a peak load basis. This is entirely in agreement with the author's object in presenting the combined natural-force-draft tower with fan auxiliary for use only during peak loads or during bad weather.

18 The objections of Mr. de Laval to the construction of the Butte tower are, however, not well taken, as the construction is more substantial than as described by him, and several years' service has not developed the defects he mentions.

19 The tests made at Detroit occurred, it is true, during the colder season, but in Par. 29 it is stated that the tower showed very little difference in operation in winter or summer—this on the advice of the chief operator.

20 Tables IV and V present the temperatures asked for to substantiate the assertion of a safe rate of heat dissipation of 200 B.t.u. per square foot per hour for the lath mat construction.

PUMP VALVES AND VALVE AREAS

By A. F. Nagle, Published in the Journal for Mid-October

ABSTRACT OF PAPER

This paper is designed to call the attention of engineers to the need of revising the common notion that "valve-seat area" is synonymous with "velocity of flow." It is evidently the purpose of specifications for pumping engines to secure a low velocity of flow through the valves, thus reducing the head required to force water through the pump; but to accomplish this laudable purpose, special and intelligent attention should be given to the *springs* of the valves, rather than to valve-seat areas. If that be done valve seat areas need not be greater than the plunger area for the vertical triple-expansion pumping engines so largely used in city pumps. A slight economy in both construction and operation could be effected by giving more study to the proper design and strength of springs for pump valves.

DISCUSSION

Charles A. Hague. The practice referred to by the author, of specifying that the area through the pump valves of waterworks engines shall bear a certain relation expressed in percentage of plunger area, is becoming less frequent, and it is to be hoped that it will finally be disregarded altogether. The relation between the plunger areas is merely incidental, because the valve area is a function of the quantity of water to be handled, the important matter being the velocity of the water through the valve seats to fill the plunger chamber as nearly complete as possible under the conditions.

2 The total valve area, or total area of valve-seat opening, ought to depend upon the velocity needed to pass the required quantity of water in a given time. Some authorities advocate a velocity not to exceed 3 ft. per sec., others 4 ft. per sec. and some as low as $2\frac{1}{2}$ ft. per sec. Two factors are to be considered, as follows:

3 First, as to the lift of the valves. The lower the pressure, and the lower the speed of the engine, the higher the valve may lift; on the contrary, the higher the pressure, and the higher the speed of the engine, the less the valve may lift, if a smooth, easy running, economical engine is desired.

4 Second, regarding the circumferential area of the valve space, or the area of the space around the edge of a disc valve, when it is open or off its seat. This is a factor that need not be very seriously considered, because the water, having succeeded in getting easily through the grating formed by the seat, will meet with very little resistance in moving out from under the valve. Valves free to lift to an unchecked height will often get so far away from their seats that slamming will take place at the reversal of the plunger. A pumping engine will work best when provided with sufficient valve-seat area to keep the mean velocity of the water down to about 3 ft. per sec., the lift of the valves being so restricted that they will return to the seats when the plunger approaches the end of its stroke.

5 With reference to plunger travel in conjunction with pump valve area, mentioned or inferred in the paper, the vital question is, How shall we obtain any certain plunger travel per minute: by a short stroke at many revolutions per minute, or, by a long stroke at few revolutions per minute?

6 After the water is well started through the pump valves, a larger increase in speed would be permissible than is found in practice, if it were not for the reversals at the end of the strokes. The 250-ft. per min. plunger travel mentioned in the paper, would be permissible with a 60-in. stroke at 25 r.p.m., or better with a 72-in. stroke at 21 r.p.m. The pump valves would work in a very satisfactory manner, the pumps would give very good hydraulic efficiency and the engines would run smoothly. But if we should attempt to obtain 250 ft. per min. with a 30-in. stroke at 50 r.p.m. there would be a great reduction in economy, smoothness of running and general efficiency.

7 The items in Par. 7 are all within the scope of mechanical efficiency, and will be reasonably well taken care of, if the valve factor is properly attended to. The most effective method for dealing with the question of valve area, is to establish a certain satisfactory area per unit of pumpage, at some definite minimum rate of revolution as a standard. Then, for every revolution per minute above the standard rate, add a certain per cent to the standard valve area. This will give an engine of more revolutions, a greater proportionate valve area than a slower machine, thus in fast engines keeping the valves nearer to their seats than in slow ones.

8 In Par. 26, the author makes a statement, with which one feels compelled to ask issue: "———the total valve area in this type of engine need not be more than the plunger area." As already pointed

out, there is no necessary relation between the valve and the plunger area at all. The relation is only incidental, or whatever it happens to be after the proper proportions are established. A certain area of plunger, with a certain stroke, at a given number of revolutions per minute sets up a certain velocity in the water through the valve seats. A plunger of half the area, with the same stroke and at twice the revolutions per minute, will set up the same velocity of displacement, and consequently the same mathematical velocity will be required through the valve seats; although the increased frequency of opening and closing will introduce another element for consideration, which will call for a greater proportionate valve area, for the greater number of revolutions per minute. In other words, a larger plunger running slowly will require the same valve area as a smaller plunger running faster, so far as the calculated displacement and velocity are concerned. The valve area in both cases depends upon the quantity of water and the selected velocity through the valve seats, regardless of the size and speed of the plungers.

9 The spring diagram and expressions are very nicely worked out, but the differentiation is too fine for real work, and could be mostly avoided by keeping the valves closer to their seats and avoiding refinement in springs. The idea is to get away from the laboratory engine, determine the conditions to be found in a pumping station, and then meet those conditions as they really exist, rather than try to adjust the working conditions to some real although impracticable refinement in some particular factor.

10 In many pumping engines now at work, some of the details worked out very nicely on the drawing board but failed to meet the actual requirements. There are waterworks engines of the cage pump construction, in which the ends of the valve stems, with valves exactly like those shown in the paper, have been sawed off, the valves being kept in place by means of wooden wedges, just because someone who never saw the inside pump after it left the shop, did not understand the requirements involved in the care and maintenance of the machine. In one or two such cases, the cages were difficult to remove, and there was not room enough to remove the valves, with the cages in the pump chamber, by the regular method of taking off the spring guard.

Irving H. Reynolds. Mr. Nagle calls attention to two very common errors which purchasers of pumping machinery fall into when preparing specifications:

a The absurdity of specifying the ratio between plunger and valve area without other limiting clauses.

b Specifying an unnecessarily large amount of valve area.

Mr. Nagle suggests as a remedy for the first, specifying *velocity* through the valves rather than a *percentage* of plunger area, and for the second, the use of lighter springs, thus enabling the valves to rise to their full lift and thereby reduce the number of valves required.

2 In regard to the first, there is an increasing tendency among engineers to specify a maximum velocity of flow through the valves rather than their area relative to the plunger.

3 Quietness of operation rather than cost is the first consideration in the design of pump valves, and the present excessive valve areas have grown from this idea. Time is also an important element in determining pump valve action; therefore, the number of reversals or valve seatings, rather than the piston speed, is the important factor, and consequently valves of small diameter and therefore of relatively low lift, have displaced the large diameters in common use a few years ago.

4 To further decrease the lift of the valves and, therefore, permit them to close quickly and quietly at high speeds, valve areas have been increased to a point where in actual operation the valves lift only a fraction of the theoretical height to which they should lift to give a full opening; in other words, large valve area is provided for the purpose of not using it.

5 If on a high-speed (high-revolution) pump the valves were fitted with light springs, permitting them to lift to their full height as suggested by Mr. Nagle, it is probable that the pump would be exceedingly noisy, as the valves would be so far from their seats at the time of plunger reversal that they would not seat until the flow through them had reversed, and this slowness in seating would be still further aggravated by the light springs employed. There is no doubt, however, that in many cases the springs used are unnecessarily stiff and on slow-speed engines the lighter springs would be found satisfactory.

6 In earlier practice, particularly with direct-acting pumps, the valve area was small in proportion to the plunger and the valves were obliged to lift nearly to their full height. In this type of pump, as the plunger speed was relatively high to nearly the end of the stroke, the valves became noisy if the pumps were operated at high speed.

7 With the general introduction of the crank and flywheel pump came higher rotative speeds and the necessity for larger valve area and smaller valve opening, i. e. lower lift, until present practice has crystallized at velocities of 3 ft. to $3\frac{1}{2}$ ft. per second through the valves, and valves of between $3\frac{1}{2}$ and 4 in. in diameter for ordinary waterworks service. In general, the best results would be obtained if engineers in drawing specifications would limit the mean velocity of water through the valves at about 3 ft. per second and the diameter of the valves to not over 4 in.

F. W. Salmon. I prefer to make these valves somewhat different from the one illustrated in the paper. I do not believe it is best to use the radical ribs of the valve seat to screw it in, but that it is better to cast small projections on the outside, as at *A* Fig 1. This part is of such a size that an ordinary black pipe will fit neatly when properly milled out at the end, thus making a good socket wrench at a minimum cost.

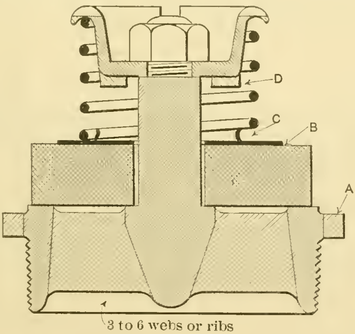


Fig. 1 Cross Section of Pump Valve, Showing Improvements Suggested by Mr. Salmon

2 I prefer to put a brass plate on the top of the rubber valve, as shown at *B* Fig. 1, and to partially punch out and turn up little projections from this plate as at *C* Fig. 1 and Fig. 2. The plate prevents the spring wearing into the top surface of the valve, and the projections keep the spring properly centered.

3 Small projections should be cast on the under side of the spring guard as shown at *D* Fig. 1 and Fig. 3, the latter being the under side

of the spring guard. If the valve is ever drawn so high as to come into contact with these projections it will still descend freely, not being in the least hindered by the soft surface of the valve forming a close contact with the smooth under surface of the spring guard, as it

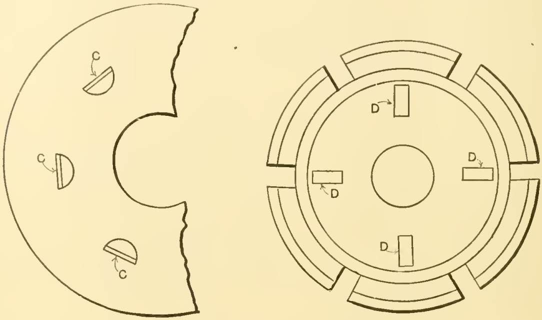


Fig 2 and 3 Showing Projections on Brass Valve Plate and on Spring Guard

is sometimes made. I consider that this is useful in cases of fast running pumps, as in such machines it is particularly desirable to have the valves seat while the crank is passing the dead center, and so a quick closing action is required.

William Kent. I hope Mr. Nagle will supplement the paper by telling us what proportion of valves and valve springs he would use for certain conditions. The paper is now largely one of criticism, and I would like to have the author make it a constructive paper. Par. 25 reads "The place to begin the study of proportions of a pump is at the spring of the valve. Make a sample spring of such diameter and length and strength as you may think desirable, and by experiment construct a diagram of its rate of compression, as in Fig. 1." This is good advice for pump designers, but other mechanical engineers are called in to confer about these points, and if Mr. Nagle would tabulate the proportions of springs suitable for pumps, and give the lifts at certain velocities of water, his paper would be more useful to these engineers.

2 The author criticises the practice of specifying the percentages of area of the valve and the pump. I see nothing very wrong

in that, provided the plunger area and the speed are also specified, as is usually done, otherwise some of the bidders will put in a small pump. In order to compel them to supply a pump large enough, we limit the velocity of the plunger; and having limited the velocity of the plunger and specified its size, we may as well say that the valve must be so many per cent of the plunger area, as to state what the velocity of the water must be. The specification is good enough, provided these additional items of plunger area and speed are also specified.

Prof. R. C. Carpenter. It is quite evident to any one familiar with hydraulics that the difficulties from the narrowing of the valve are largely inherent in the spring. If a spring could be obtained which would open uniformly with increase of pressure the troubles due to certain inertia effects which are mentioned, would disappear. This, however, merely points out the source of trouble and leaves the question open as to what shall be done. In substance, defects are merely pointed out without remedies. I would suggest, if Mr. Nagle can, that he give some of these remedies for the troubles which he has described.

E. H. Foster. Attention should be called to the fact that this paper refers to the valves of one type of pump. Many pumps of other types are built, particularly those without fly wheels, to which it is not absolutely necessary that these rules should apply. It is well known that a considerable pause at the end of the stroke of the duplex pump facilitates the closing of the valves, so that these empirical rules for lift and area must be quite different for that type of pump.

The Author. Some new matter which has come to the attention of the writer of this paper, is appended herewith. A careful study of this will answer most of the points raised in the discussion, especially the point made by Mr. Reynolds and Mr. Hague, to the effect that the maximum velocity through the valve should be limited to 3 or 4 ft. per sec. It can be assured that the formula and Table 1, quoted from Professor Bach's experiments governing the relation of spring pressure and velocity of flow to the coefficient of contraction, is correct.

TABLE I PROFESSOR BACH'S EXPERIMENTS WITH A FLAT VALVE AND A FLAT SEAT (SEE FIG. 1)

Inside diameter of valve seat d = 1.968 in. Outside diameter of valve d_1 = 2.362. Ratio of inside and outside areas, 1 to 1.44. Inside area, 3.04 sq. in.

			H = 1.27 – 1.29 ft.		H = 3.08 – 3.11 ft.		
1	M = lift of Valve, in..........	0.23	0.55	1.01	0.122	0.40	0.65
2	G = Weight of valve, lb......	2.028	2.218	2.304	4.610	5.073	5.238
3	Q = Volume of water, lb. per sec..............................		6.548	8.554	3.086	6.768	11.20
4	H = Head of water, ft........	1.29	1.29	1.27	3.11	3.10	3.08
5	W = Velocity through seat. ft. per sec..........................		4.97	6.46	2.33	6.17	8.46

Calculations by Nagle

6	$\frac{m}{d}$ = Ratio lift, to diameter.	0.12	0.28	0.51	0.06	0.20	0.33
7	G = p Weight per sq. in., lb. per sq. in...........	0.666	0.728	0.760	1.516	1.668	1.723
8	V_g = Velocity due to p, ft. per sec...............	9.55	9.47	9 07	14.70	14.72	14.35
9	V_h = Velocity due to H, ft. per sec................	9.12	9.12	3.92	14.14	14.10	14.07
10	Ratio of $\frac{V_g}{V_h}$....................	1.04	1.04	1.02	1.04	1.04	1.02

Line 7 is obtained by dividing the weight G, given in line 2, by the area of d, or 3.04 sq. in.

Line 8 is obtained by the aid of Table 2, where opposite the value of $\frac{m}{d}$ is found the coefficient and formula. For example: taking the first case of a lift of 0.23 in., or a percentage of 0.12 of the diameter 1.968 in., we find by interpolation in Table 2, the formula, $V = 1.17\sqrt{100\,p}$, or $V = 1.17 \times 8.16 = 9.55$ ft. per sec.

Line 9 is obtained from the fundamental hydraulic formula $V = 8.025\sqrt{H}$, when H is the head in feet and V the velocity in feet per second. For example, in the first case cited we have, H = 1.27 ft. $V = 8.025\sqrt{1.27}$, or = 9.12 ft. per sec.

Line 10 is self-explanatory, and is introduced as a check upon the work and formulæ, as if correct, it should be unity. The slight deviations are due to the various decimals not being carried far enough, but they are carried far enough for all practical purposes.

TABLE 2

1	$\frac{m}{d}$ =	....	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.5d
2	u =	....	0.65	0.60	0.56	0.53	0.50	0.47	0.44	0.41	0.37
5	p =	0.67	0.69	0.72	0.74	0.77	0.80	0.83	0.86	0.89	0.92 $\frac{V^2}{100}$
6	v =	1.22	1.20	1.18	1.16	1.14	1.12	1.10	1.08	1.06	$1.04\sqrt{100p}$

Line 1 $\frac{m}{d}$ is the actual rise, or lift, of the valve, divided by its inside seat diameter.

Line 2 u is the coefficient of contraction at the point of discharge with a given lift.

Line 4 V is is the velocity of the issuing stream at the point of discharge in feet per second.

Line 5 p is the pressure in pounds per square inch and is found by dividing the weight of the valve (in water), plus its spring pressure in pounds by its inside seat area in square inches.

Line 6 v is the velocity of the issuing stream per second.

2 Let us apply the formula to the 3 ft. per sec. assumption. For a lift of, say, 0.20 × diameter,

$$p = 0.77 \times \frac{V^2}{100} \text{ or } = 0.07 \text{ lb. per sq. in.}$$

of inside seat area. Such small spring pressure is out of all proportion to what common practice has established, which is from 0.30 to 0.60 lb. at the initial and 0.75 to 1.50 lb. at the full lift. The formula for the resulting velocities is very simple. Suppose we solve for four spring pressures of, say, 1.50, 1.25, 1.00 and 0.85 lb. at full lift, and 40 per cent, or 0.60, 0.50, 0.40 and 0.34 lb. at the initial point. at a lift of 0.20 × diameter, the formula would be

$$V = 1.14 \sqrt{100 \times p}$$

and the velocities for

$$\begin{aligned} p = 1.50 \text{ lb.} \quad & v = 13.96 \text{ ft. per sec.} \\ 1.25 \text{ lb.} \quad & v = 12.74 \text{ ft. per sec.} \\ 1.00 \text{ lb.} \quad & v = 11.40 \text{ ft. per sec.} \\ 0.85 \text{ lb.} \quad & v = 10.51 \text{ ft. per sec.} \end{aligned}$$

The coefficient of contraction would be 53 per cent in each case.

3 It is plain, therefore, that we are far from realizing four feet per second with our present spring practice.

4 To Mr. Reynolds: The writer did not mean to lighten the springs abnormally, in fact, 0.45 lb. to 0.50 lb. initial is probably light enough, but if they could be made somewhat longer, so as not to tighten up too rapidly, it would seem to be desirable.

5 To Mr. Kent: The formulæ given by Professor Bach are a very great addition to our knowledge of pump-valve action. Within the limits prescribed, we have now a safe guide for valve construction. What it should be for other numbers of revolutions and plunger velocities, I am not able to formulate. Professor Haeder goes into that phase of the problem, but as his theory is not confirmed by extensive experience, I do not take it up in this paper.

ADDENDUM TO PAPER

6 In Par. 15 of the paper is given a formula for ascertaining the lift of a pump valve, from which was omitted, as stated, the coefficient of contraction. Not knowing the value of this coefficient with certainty, the writer hoped the information would be supplied in the dis-

cussion. The omission was not referred to, however, and he is now able to supply it himself.

7 In a German book on pumps and pump valves by Herm. Haeder, Duisburg, the subject is treated in an exhaustive manner. The actual coefficients of contraction are given, with the results of impact upon the valve, based upon experiments by Professor Bach. In what follows reference is made only to that part which bears on the subjects of flat valves and flat seats, of which the inside and outside areas bear the ratio of 1.00 to 1.44. The notations were originally in French, but in what follows have been transformed into English units.[1]

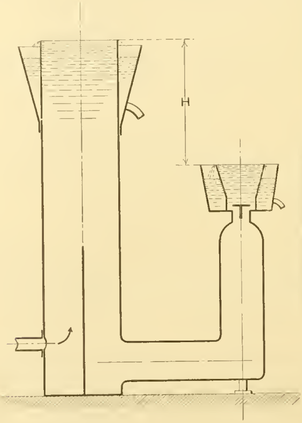


Fig. 1 Apparatus used by Professor Bach for Determining Coeffcient of Contraction

8 Fig. 1 shows the apparatus used by Professor Bach. Table 2 (Haeder 261) gives the original data and results obtained and some calculations of my own, the better to elucidate the subject.

9 Fig. 2 and Fig. 3 (Haeder 110 and 110a) show a valve closed and one open, with the respective formulæ for the two positions of the valve, giving the values for velocity or pressure in the two extreme positions. "Open" signifies a lift of one-half the diameter, which, needless to say, is far beyond American waterworks practice.

[1] The original tables in French units can be referred to in the author's manuscript on file in the rooms of the Society.—Editor.

10 Table 2 (Haeder 213) gives the values of v and p for the intermediate positions of the valve, and also the value of "u", the all-important coefficient of contraction at all positions. Use this table to ascertain the velocity v of the water through the valve opening and also the coefficient of contraction u at the same point.

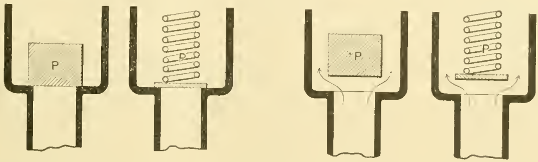


FIG. 2 AND FIG. 3 SHOWING, RESPECTIVELY, A VALVE OPEN AND A VALVE CLOSED. THE FORMULAE FOR THESE TWO POSITIONS ARE AS FOLLOWS:

V = VELOCITY IN FEET PER SECOND P = POUNDS PER SQUARE INCH

VALVE CLOSED	VALVE OPEN
$V = 1.22 \sqrt{100 P}$	$V = 1.04 \sqrt{100 P}$
$P = 0.67 \dfrac{V^2}{100}$	$P = 0.92 \dfrac{V^2}{100}$

11 We can now say that we have a practically correct formula for ascertaining the volume of water discharged through a flat disc pump valve of a certain diameter, an assumed lift, and a certain tension of spring.

12 Throughout all the following calculations a maximum lift of valve of 0.15 d, is taken, leaving the reader to make for himself other assumptions of lift and the consequent calculations. Various tensions of springs will be taken, to illustrate the importance of giving more attention than heretofore to the strength and length of springs.

13 Take, for examples, the same dimensions of pump and valve as those used in Par. 16. Formula 3 (Par. 15) would now be better expressed in terms of N, the number of valves, than assuming the number of valves and solving for the lift L. The formula would then read,

$$N = \frac{P \times V_m}{C \times L \times u \times V_m}.$$

Applying this formula to the three different strengths of springs before used, we get the following results:

14 First, ascertaining the velocity through the valve by the aid of Table 2, the spring tensions were as follows;

Case 1: initial, 0.60 lb.; final 1.55 lb. per sq. in.
Case 2: initial, 0.40 lb.; final 1.03 lb. per sq. in.
Case 3: initial, 0.30 lb.; final 0.77 lb. per sq. in.

The formula for the velocities due to these final pressures at a lift of 0.15 d, are

$$\text{Case 1: } V = 1.16\sqrt{100 \times 1.55}, \text{ or } V = 14.41 \text{ ft. per sec.}$$

$$\text{Case 2: } V = 1.16\sqrt{100 \times 1.03}, \text{ or } V = 11.77 \text{ ft. per sec.}$$

$$\text{Case 3: } V = 1.16\sqrt{100 \times 0.77}, \text{ or } V = 10.18 \text{ ft. per sec.}$$

The coefficient of contraction in each case is $u = 0.56$. Substituting these values in Formula 4, we have,

$$\text{Case 1: } N = \frac{908 \times 6.67 = 6056}{10.53 \times 5.625 \times 0.56 \times 14.44} = 127$$

$$\text{Case 2: } N = \frac{6056}{3.317 \times 11.77} = 155$$

$$\text{Case 3: } N = \frac{6056}{3.317 \times 10.18} = 180$$

15 Let us make a similar calculation for springs of the same initial strength, but longer, so that they will tighten only one-half as much in their nine-sixteenths lift. Then the first spring final tension becomes 1.08 lb., the second spring 0.72 lb., and the third spring 0.53 lb.; and the velocities become

$$\text{Case 1: } V = 1.16\sqrt{100 \times 1.08} = 12.05 \text{ ft. per sec.}$$

$$\text{Case 2: } V = 1.16\sqrt{100 \times 0.72} = 9.84 \text{ ft. per sec.}$$

$$\text{Case 3: } V = 1.16\sqrt{100 \times 0.56} = 8.68 \text{ ft. per sec.}$$

and solving for N in formula 4, we have

$$\text{Case 1: } N = \frac{6056}{3.317 \times 12.05} = 152$$

$$\text{Case 2: } N = \frac{6056}{3.317 \times 9.84} = 186$$

$$\text{Case 3: } N = \frac{6056}{3.317 \times 8.68} = 210$$

16 To calculate the loss of efficiency for these different springs let us take the mean pressure on the springs to be the initial, plus two-thirds of the increase, and twice this for the two strokes; and this sum must be divided by the total pump head, say 80 lb., to obtain the loss of efficiency. We would then have

Case 1: $[0.60 + (1.55 - 0.60)\ \frac{2}{3}] \times 2 \div 80 = 3.06$ per cent
Case 2: $[0.40 + (1.03 - 0.40)\ \frac{2}{3}] \times 2 \div 80 = 2.05$ per cent
Case 3: $[0.30 + (0.77 - 0.30)\ \frac{2}{3}] \times 2 \div 80 = 1.50$ per cent

With stronger springs, we would have

Case 4: $[0.60 + (1.08 - 0.60)\ \frac{2}{3}] \times 2 \div 80 = 2.30$ per cent
Case 5: $[0.40 + (0.72 - 0.40)\ \frac{2}{3}] \times 2 \div 80 = 1.50$ per cent
Case 6: $[0.30 + (0.53 - 0.30)\ \frac{2}{3}] \times 2 \div 80 = 1.15$ per cent

Grouping these figures for better comparison, we have Table 3.

17 We have now, in Table 3, figures which enable us to study pump valve constructions in an intelligent manner. The formulæ given enable us to construct a similar table for any other assumed dimension of plunger and its velocity, height of lift of valve, or spring tension.

18 In conclusion the writer wishes to say that now, for the first time in the history of the modern high-duty pumping engine, we have a formula for designing a pump valve that is scientifically correct, and one based upon hydraulic experiments carefully made by a competent authority. The subject seems important enough to bear repetition in grouping the previous instructions, as follows:

19 Find the area of the plunger in square inches, and the maximum speed of the plunger in feet per second. The latter is found by multiplying the stroke in feet by the maximum number of revolutions per minute, multiplying this result by 1.60, to reduce it to its maximum velocity (the crank velocity), and dividing by 60 to reduce it to feet per second. This product, algebraically expressed by $P \times V_m$ in Formula 4, becomes the numerator of the equation.

20 Determine the size of the pump valve-seat and its net area between the ribs, whether the valve bears on the ribs or not; that will be the inside area of the valve against which the impinging stream acts.

21 Decide what lift of valve you intend to have. American water works practice is from 0.10 to 0.20, the diameter of the inside of the outer seat. This lift is designated by L in the formula.

22 Decide what spring pressure you will have, both at the beginning and at the full lift. This spring pressure is expressed in pounds

per square inch of inside valve area and usually runs from 0.30 to 0.60 lb. per square inch at the beginning of the lift, and it ought not to be quite double this amount when the valve is full open to its stop. It will be this final tension, plus the weight of the valve in water, designated by p in Table 2, that will be the determining factor for the velocity of the issuing stream. To illustrate, if the final pressure be 0.81 lb. per sq. in., with a lift of 0.15 d, the equation (see Table 2) for $V_m = 1.16\sqrt{81} = 10.44$ ft. per sec.

23 The discharging area is the net circumference of the inside valve diameter C, taking out the ribs whether they support the valve or not, multiplying this by the actual lift and this product by the coefficient of contraction u, as found also in Table 2, which, for the lift cited, is 0.56.

24 Algebraically expressed, these factors become the denominator in the Formula 4,

$$N = \frac{P \times V_m}{C \times L \times u \times V_m}$$

TABLE 3 $\frac{9}{16}$ IN. LIFT

PLUNGER 34 IN. DIAMETER BY 5-FT. STROKE BY 25 R.P.M. MAXIMUM VELOCITY = 6.67 FT. PER. SEC. VALVES $3\frac{3}{4}$ IN. INSIDE DIAMETER. NUMBER OF VALVES, SPRING TENSIONS AND PUMP EFFICIENCIES.

	Initial and Final Spring Tension Pounds	Valve Seat Area Per Ct.	Number of valves	Lift of valves Inches	Maximum Velocities Feet per Second			Loss of Efficiency Per Ct.
					Plunger	Valve Seat	Valve	
1	2	3	4	5	6	7	8	9
1.	0.60 to 1.55	112	127	$\frac{9}{16}$	6.67	5.96	9.44 – 14.44	3.08
2.	0.40 to 1.03	137	155	$\frac{9}{16}$	6.67	4.87	7.71 – 11.77	2.05
3. .	0.30 to 0.77	159	180	$\frac{9}{16}$	6.67	4.20	6.68 – 10.18	1.50
			Longer Springs					
4. .	0.60 to 1.08	134	152	$\frac{9}{16}$	6.67	4.98	9.44 – 12.05	2.30
5. .	0.40 to 0.72	164	186	$\frac{9}{16}$	6.67	4.07	7.71 – 9.84	1.52
6.	0.30 to 0.53	185	210	$\frac{9}{16}$	6.67	3.60	6.68 – 8.68	1.15

Column 3 is obtained by multiplying the number of valves by the net area through the seat (8.00 sq. in.), and finding its ratio to the plunger area.

Column 5 is taken at $\frac{9}{16}$ in. = $(0.15 \times d)$ in all cases.

All the other data have been already explained.

AN EXPERIENCE WITH LEAKY VERTICAL FIRE-TUBE BOILERS

By F. W. Dean, Published in The Journal for October

ABSTRACT OF PAPER

This paper discusses the difficulties experienced with some large vertical boilers, somewhat over 10 ft. in diameter, and containing over 6000 sq. ft. of heating surface. The boilers leaked very badly very soon after being started and nothing that was done improved their condition until the water legs were lengthened from 2 ft. to 7 ft. 2¾ in. The boilers were raised 5 ft. 2¾ in. Before they were raised the lower ends of the tubes would cover with very hard clinker and become stopped up. This clinker could be removed only by cutting it off when the boilers were cold. After the boilers were raised, a light clinker that could be blown off formed about the tubes; by removing this by blowing every three or four hours the leaks were stopped and they have never returned.

The trouble varied with different kinds of coal Each boiler had been run constantly at over 1000-h.p. and the economy seemed to be about the same no matter what the power was. So far it has been difficult to obtain good combustion, but the heat-absorbing power of the boilers is admirable. The experience with these boilers indicates that there is no ordinary limit to the size of a vertical fire-tube boiler.

DISCUSSION

Reginald P. Bolton. It appears to me that this design of boiler was an invitation to the trouble that followed, and it is only necessary to go back into the experience of other people to find out that others have suffered in the same manner. If the view of the boiler as presented in the paper is turned horizontally, and it is imagined that it is a locomotive boiler cut off short, it will be seen that there is no combustion chamber whatever in it. This boiler was to be put to a service which might call for a rate of combustion in the furnace which would demand double its rated capacity output, so that the double aggravation of a very small combustion chamber and very large rate of combustion, was present.

2 The design of the boiler is radically defective in two important points, namely, the tubes are entirely too long, and the combustion space was entirely too small. It is now very nearly half a century ago that the experiments of Geoffroy and Petiet demonstrated the futility of unduly lengthening fire tubes. These experi-

ments demonstrated the rapid reduction in efficiency due to length of tubes, under various conditions of draft and rates of fuel consumption. Almost precisely the same conditions were tested as in the author's boiler, as follows:

3 A consumption of fuel exceeding 50 lb. per square foot of grate, under an air pressure of 2.36 in. with the following results:

	Evaporation per Sq. Ft. Lb.
Fire-box plate	23.5
First three feet of tubes	5.4
Second " " " "	2.5
Third " " " "	1.33
Fourth " " " "	0.83
Fifth, three feet evaporated only	0.48
Sixth " " " "	0.3

The last two were found by extending the curve.

4 An examination of these results might have dissuaded the author from the mistake of designing the boiler with such a length of tube, involving not only inefficiency, but the evident concomitant of leakage as a result of expansion and contraction. Apart from the other defective feature, the boiler could have been shortened so as to reduce the tubes at least five feet in length, and would no doubt have given better efficiency as a result.

5 The general type of the boiler possesses nothing new or original unless we may so regard the restricted combustion chamber, by which the tube plate was brought within seven feet of the grate, allowing a total capacity of only 535 cubic feet for the fire and for the gases of combustion.

6 A very simple computation of the results of the combustion of 40 lb. of coal per square foot of grate area, will show that the volume of products of combustion would be so great, that only an excessively heavy draft could force them through the combustion chamber and tubes, and that incomplete combustion was bound to result.

7 The addition of 5½ ft. to the height of the chamber, which was arrived at only after three years experience with this boiler, nearly doubled the effective space for combustion, and also removed the ends of the tubes from the direct action of the blast. It may be observed that a Dutch oven would have afforded equal results, at perhaps less expense.

8 The reason for the adhesion of molten clinker to the ends of the tubes, need have presented little difficulty, in the light of past

experience, since the ends of the tubes were placed so close to the fire. This result developed in the fire-tube boilers of H. M. S. Polyphemus nearly thirty years ago, and when found in the boilers of locomotives is due to precisely the same cause.

9 It will be noticed that the best of the tests which were made after the change of combustion chamber was effected, is that in which the rate of fuel consumption is least.

10 I agree with the quoted conclusion of the second boiler expert, referred to in Par. 6, and am at a loss to understand why such an opinion, thus expressed, was regarded as unsatisfactory. It may be hoped that the paper may stand as a warning signal to other designers. It requires a great deal of courage to present a paper of this kind, and the author should be thanked for bringing forward a record of a failure so that we may profit by the facts.

William Kent. I join with Mr. Bolton in praising Mr. Dean's courage in bringing forward a report of his failure, and I regret that some eight or ten years ago I did not bring forward a record of another similar failure, not my own, but that of some other man, which might have prevented Mr. Dean's bringing forward a record of this failure. The New York Steam Company bought a boiler for their Greenwich Street Station to go in a very small ground space. It was a very large plain vertical cylinder boiler, eight or ten feet in diameter, full of tubes about 20 ft. long, and was rated at 1000 h.p. It had not been in use more than a week or two when it began to leak. There was no way to clean the flat tube sheet or to clean the tubes of scale, and the boiler was condemned and taken out.

J. C. Parker. The reason that the tubes leaked was that when the boiler was set close to the grate the tube ends were subjected to wide fluctuations in temperature. The flow of air through a chain grate increases toward the rear end, and where the boiler was set higher there was more mixing of the hot and cold currents and, consequently, less fluctuation in temperature.

2 The clinkering of the tubes would naturally increase the trouble because of the concentration and increased friction of the gases in the tubes that remained clear.

Orosco C. Woolson. This discussion has brought out the important fact that perfect combustion should take place before the gases reach the tubes or shell of the boiler.

2 I have been somewhat surprised in my travels among the cotton and woolen mills of the Eastern States where the management have large experience in cotton spinning but are limited in personal experience regarding what constitutes the production of the highest calorific value of a pound of bituminous coal. One man of large experience in mill work wanted his furnace fire directly under the tubes of his vertical boilers, and gave me his reasons. I told him that I would guarantee him better results if he would discard the idea that the area immediately under and against the tube sheet should act as a combustion chamber. Let combustion take place entirely before it reaches the tube sheet and the results will be much more satisfactory.

3 Secondly, as to the tubes filling with vitrified slag or any other residuum of combustion, I would suggest that such deposit should be made to take place under a fire arch, where it will adhere to the crown and serve a useful purpose by forming a refractory coating. This practice is becoming popular, and more so today than ever before. It is my opinion that by completing combustion under a properly constructed arch within a properly constructed combustion chamber, the products of this combustion will be sent to the boiler in the form of what we will term "caloric ether" and not a mixture of its original constituents which play no useful part, under the circumstances, in producing or maintaining heat, but rather are subject to ready condensation.

A. A. Cary. In my experience with vertical fire-tube boilers I once found a boiler containing shorter tubes and of a greater diameter than are ordinarily found in the Manning type. The fuel used was a moist anthracite coal, and there was a natural draft of more than one inch of water in the smoke box over the boiler. The draft could not be regulated, due to the previous burning out of the steel plate butterfly damper. The partially burned furnace gases passed rapidly through the vertical tubes and ignited above the top tube sheet, thus causing the destruction of dampers and the steel breeching, to say nothing of the reduced evaporation in the boiler due to this waste of heat.

2 The trouble was remedied by placing the grates at a greater distance from the lower tube sheet and arranging baffles in the combustion chamber so as to insure the more complete combustion of the gases before they entered the tubes. A cast-iron plate damper replaced the former one of steel plate, and no further trouble has since been experienced.

3 In another case, the question came up as to the advisability of applying a special automatic furnace, using bituminous coal and producing very high temperatures, under boilers of the Manning type. An arrangement which has been used in New York City for a number of years was suggested and successfully applied.

4 Fire-bricks, piled on edge with open spaces between the bricks, were arranged a short distance beneath the lower tube sheet. This checker work of bricks filled the entire space beneath the boiler, the openings between the bricks at the center being very much reduced, so as to cause a decreased flow of gases directly under the center of the overhead tube sheet. By this means, a very even distribution of temperature was secured over the entire area of the lower tube sheet with a slight reduction of heat delivery at its center, the most sensitive portion of the whole tube area.

5 The author mentions inefficient combustion, which is indicated by the comparatively low percentage of CO_2 and high percentage of O, shown in Table 1. As the higher temperatures are secured by the most complete combustion with the least excess of air, the question arises, why should such destructive results follow such inefficient furnace conditions?

6 Pyrometric testing with gas analyses have taught me that when a furnace is being operated inefficiently, very high temperature may be found in one part of the furnace while at the same time a comparatively low temperature may exist in another part. This may lead to the simultaneous impingement of gases of very different temperatures upon various parts of the lower tube sheet, setting up destructive strains and contributing to such troubles as have been described by Mr. Dean.

7 The lower tube sheets of boilers of the Manning type are very sensitive, especially towards the center of the sheet where the water seems to penetrate with great difficulty, thereby failing to keep this portion of the heating surface constantly wet.

8 Concentration of heat due to concentration of combustion and lack of space for this small volume of high-temperature gas to diffuse itself throughout the entire mass of furnace gases before they reach the tube sheet, is bound to cause trouble, especially when this highest temperature is concentrated against the center of the tube sheet on the inner surface of which there is apt to be little or no water. After the center of this sheet loses the supporting effect of the center tubes, acting as stays, the surrounding tubes are very apt to follow.

9 Concerning the low efficiency of the furnace referred to in

Par. 13, there should be no trouble in remedying this fault. A properly conducted furnace test (apart from the boiler) with pyrometers, gas analyzing apparatus, etc., will show just where the trouble exists and will point out the needed changes as well as the limitations under which this type of stoker can be worked with the different grades of fuel used.

Prof. L. P. Breckenridge. One of the speakers said that the highest temperature in a boiler furnace is directly over the fire. This is not always so. We have measured the temperature twenty feet from the fire and found it higher. It depends on the volatile content of the fuel and whether the flame has been supplied with a sufficient amount of air early in the process of combustion. It is this that determines whether the high temperature point is ten feet or twenty feet away. Many times in our experiments in the St. Louis boiler trials we have seen that every time the furnace door was opened the temperature at the rear end of the combustion chamber went up, because when more air was admitted the combustion was better and the temperature increased.

2 For experiments concerning the transmission of heat through a boiler tube, it occurs to me that Mr. Dean has designed one of the most satisfactory laboratory boilers I have seen. There has been much discussion of late on the heat transferred through a boiler tube, as influenced by the velocity of the gases passing through the tube. This boiler with its large number of tubes would be just the type with which to make a test on this point. I wish Mr. Dean would burn a large amount of coal per square foot of grate in this boiler furnace, using, first, all the tubes, and secondly, only one-half the tubes. If the same amount of coal was burned in each case the velocity of the gases through the tubes would be twice as great in the second case, and it would be interesting to know the relative amounts of heat transferred.

3 I hope that some time we may take up the question of the burning of fuel, making a distinction between the economical performance of the boiler and of the furnace. We have reached a time when we can intelligently discuss these questions separately. Anthracite coal, on account of its high fixed-carbon content, is burned mostly on the grate itself. When burning semi-bituminous coal, with 18 to 20 per cent volatile content, a large combustion chamber is required, and as the volatile content increases the size of the combustion chamber must be increased. When burning bituminous coal, with

40 per cent volatile content and 20 per cent ash, the fuel actually burned on the grate is small. The grate supports the fuel and some coal is burned there, but it is in the combustion chamber that we burn fully one-half the combustible part of our fuel. It is evident that more attention must be given the proportions of our combustion chambers when burning high-volatile coals, and especially at high rates of combustion.

Prof. A. M. Greene, Jr. In London Engineering for October 22 and November 5, 1909, appeared an article by Professor Dalby, in which he summarized a number of articles referring to heat transference through plates. I would commend the article to the attention of all the members of the Society interested in this matter.

2 In London Engineering for Feb. 1909, Professor Nicholson described experiments showing clearly that only a small part of the possible heat transmission through plates is utilized. I mention this to call attention of the members to the fact that some data are available on this subject. In this article are given the formulæ for heat transmission which may by compared with the results of German Experiments recently completed at Dresden (Zeit. des. Verein Deutscher Ing., October 23, 1909).

William Kent. In another issue of London Engineering, a correspondent showed that the idea of high speed of the gases being favorable to combustion was negatived by the Lancashire boiler, in which the flues are very large and the speed of the gases low, yet the economy is as high as in any other boiler.

Reginald P. Bolton. It is mainly a question of the difference in temperature between the inside and outside of the heating surfaces. The lower the temperature of the feed water, and the higher the temperature of the fire, the greater will be the efficiency of the boiler.

E. D. Meier. I find myself in substantial agreement on some points with all the gentlemen who have spoken. I want to say for Mr. Dean, that he is correct in his conclusion that the precipitation which occurs at the bottom of the tubes has a great deal of influence on the overheating of the tube sheet. The other causes which were mentioned are also true, but there is no doubt an accumulation of carbon there. I do not know whether Mr. Dean preserved any of the

precipitate or stalactites, but I believe a large part of it was unconsumed carbon, which will remain at a high temperature for some time.

2 I am reminded of an experience which I had with water-tube boilers at the Chicago World's Fair. I think there were ten different makes of water-tube boilers, most of them sub-horizontal, but some of the vertical-tube type and some of the bent-tube type. We were burning crude oil, and all the boilers suffered from the same causes, —every one lost tubes by burning out. Some were careful enough to shut down a boiler as soon as they noticed the blisters on the tubes.

3 The boilers which I had at Chicago were afterward placed in the midwinter fair at San Francisco, and were fired with California crude oil for seven months without a tube being lost. These boilers were afterwards sold with the condition that if the customer found any tube damaged it would be replaced, but not one was found to be burned. That bears on the subject mentioned by Mr. Dean. The trouble we found was this: The oil is supposed to be atomized in the burners, but this is not always the case. Little slugs of oil would fly up and adhere to the tube, and would spread and slowly carbonize. They would not burn, because no air could get to them. One little spot, a half inch in diameter, would become red hot in spite of all the circulation of water, and would ultimately burn out and make a blister.

4 When the boilers were installed in California, the oil burners were placed lower and were directed downward so that the jet would strike the bottom of the combustion chamber at a distance of six feet from the front, hence there was no chance of oil striking the tubes. Perfect combustion was obtained, and on one occasion one of the boilers was forced so hard that a picture was taken of the inside of the furnace by its own heat. I have that photograph still, to show what can be done. One can see a perfectly white heat and not a single blister on the tube. In Mr. Dean's case carbon was deposited and became incandescent, and gave an intense local heat on some point, which accounts for the failure of the tubes at such point.

5 In regard to the combustion chamber, I agree with Professor Breckenridge. I have always been a believer in a large combustion chamber, and one of my early experiences in that direction was when in charge of a plant having two horizontal tubular boilers, using Illinois coal. At that time everybody in the Mississippi Valley believed in river practice. The boilers, engines and dimensions of pipes, etc., were according to river practice. The boilers were set with the grate twelve inches from the bottom of the shell. I

raised them to thirty inches, and I was told I would not get any heat, but I got better results, and the boilers lasted longer. The increase in the distance from the fire to the shell was a great advantage, and, of course, incidentally I increased the efficiency of the boiler.

David Moffat Myers. In Table 4 of my paper on Tan Bark as a Boiler Fuel, during the efficiency test the temperature inside the furnace was 1100, the temperature in the combustion chamber, under the boiler, was 1475, the flue temperature was 493, and the thermal efficiency was 71.1 per cent.

2 These figures prove that under conditions of good efficiency it is quite possible to have a higher temperature at some distance from the fuel than close to it. The combustion of the gases is simply retarded to a later point of their travel. This might be caused by the combination of a high velocity of draft with a moderate air supply, so that the oxygen does not come into sufficiently intimate contact with the fuel gases in the primary combustion chamber, that is, in the furnace proper. In the case quoted, the CO_2 ran almost uniformly at about 12 per cent, the O between 6 and 7 per cent, with no determinable CO.

A. Bement. In the boiler which Mr. Dean describes, I like the scheme of having the rear end of the chain grate exposed so that it is accessible. The capacities obtained with these boilers are very large; the strength of draft, however, is somewhat too much for an ordinary chain-grate fire. It is my experience that chain grates are not proportioned so that it is possible to carry the requisite thickness of fire for a draft such as existed in this case. I think this will account for the low percentage of CO_2 in the combustible gases, and in this is found the reason why the efficiency was not higher.

2 I would attribute the leaking of the tube ends in the head over the fire to another cause than that given. Considerable experience in similar cases leads me to believe that the trouble is caused by excessive heating on the delicate tube ends in the flue sheet. There are two thicknesses of metal to be penetrated before the heat reaches the water; also the opportunity for water to enter among the tubes and to flow freely over the heated parts is rather restricted. When the ordinary return tubular boiler is set with a fire under the shell, a large portion of the heat flows through the shell, with the result that the temperature of the gases is much reduced, so that by the time they impinge upon the tube sheet, their temperature is low enough so that no damage results.

3 A case of trouble of this kind is illustrated by Fig. 1 and Fig. 2, the first showing a return tubular boiler set against an enclosed fire-brick furnace, in which the gases first impinged upon the tube sheet, passing through the tubes to the other end of the boiler, thence find-

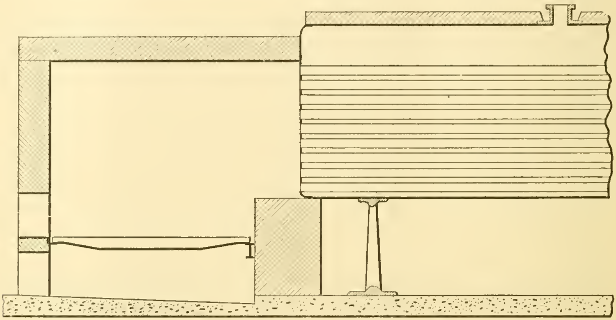


Fig. 1 Setting of a Fire-tube Boiler in Which the Tubes Leake

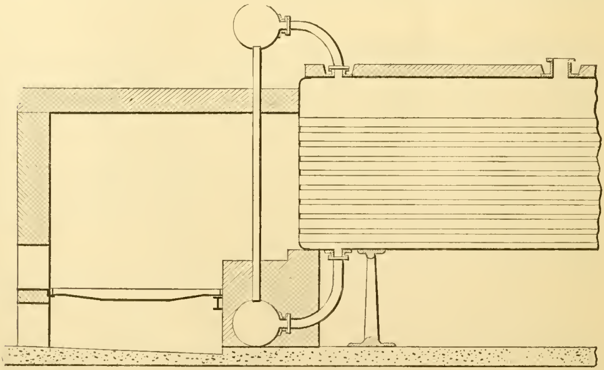


Fig. 2 Showing Water Leg to Lower Temperature of Gases Impinging on Tube Sheet

ing exit by way of a chimney attached thereto. When these boilers were put at work immediate and very serious trouble resulted with the tube ends; they leaked very badly, the bead getting out of shape and springing away from the sheet. By means of a little door in the

side of the furnace one could see the water squirting from every tube, and running away from the setting on the floor in a large-sized stream.

4 A remedy was effected in this case, as shown by Fig. 2, by mounting above and below the furnace a drum which extended crosswise of the setting, and connected by vertical 4-in. boiler tubes as indicated; each of these drums being in communication with the boiler, allowed circulation of water and steam. With this scheme the gases first pass between these vertical tubes, which are set closely together, with the result that there is a considerable reduction in the temperature of the gases before they came in contact with the end of the boiler tubes.

5 Another case of this character was remedied by carefully cleaning off the end of the boiler and coating it with an asbestos cement, which was rounded over and into the boiler tube openings in such a way that the flue sheet was entirely protected. This covering lasted about three months, after which it was necessary to renew it. As it was a house-heating boiler, two renewals a season served until the boiler plant was dismantled. The cure of the trouble with the boiler having the extended water leg, as shown in Fig. 2, is due in my opinion to the added heat-absorbing surface in the deeper leg, as it operates to abstract a much larger quantity of heat from the gases before they came in contact with the tube ends, than did the boiler before alteration.

The Author. Replying to Mr. Bolton's remarks, I have heard of the experiments which he quotes in regard to the rate of evaporation of different portions of the length of a tube, but I am not at all impressed with them as a guide. It is well known that the first surface that receives heat gives the greatest rate of evaporation and leaves less for the remaining surface to do. Attention to this to the extent apparently advocated by Mr. Bolton would lead to an absurd result, for one might go on indefinitely shortening tubes. It should be remembered that only 16 ft. of the 20 ft. length of tubes are in contact with water, the remainder being for superheating.

2 Apparently Mr. Bolton believes that it is known how long tubes should be. I do not think that this is known, for the reason that a boiler must undergo a wide range of duty: a short tube would do for light work and a long one would be necessary for heavy work. Many vertical boilers with 2½ in. tubes 20 ft. long have been used successfully for years and they are still being built. Mr. Bolton would evidently prohibit increasing the size of a boiler by increasing the

length of tubes, and would recognize only an increase in diameter as a means of increasing size. To my mind this is illogical and not consistent with the teaching of successful practice.

3 Mr. Bolton speaks of the small combustion chamber as the boiler was first installed, but he ignores the hundreds, if not thousands, of vertical boilers with less combustion chamber space. I believe that I am the only person who designs vertical boilers with the crown sheet as much as 8 ft. above the grate, and this I have been doing for

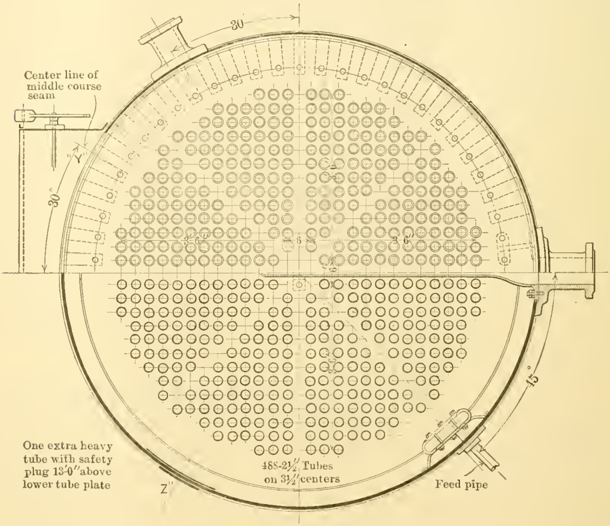


Fig. 1 Cross Section of Vertical Fire-Tube Boiler Designed by the Author

many years. In regard to the Dutch oven in front of these boilers, it would have wholly defeated the object of using vertical boilers. Besides it would have added undesirable brick work.

4 Mr. Bolton easily accounts for the lack of economy of the boiler, but ignores the perfection with which it absorbs heat. I believe the lack of economy to be wholly due to want of air, and when this is supplied and properly distributed the economy will be satisfactory. This would be equally true if the combustion chamber were much longer. The locomotive boilers tested at the St. Louis Exposition by the Pennsylvania Railroad have very little combustion chamber

space, and the excellent economy is due to the proper admission and distribution of air. In regard to the economy of the boilers under

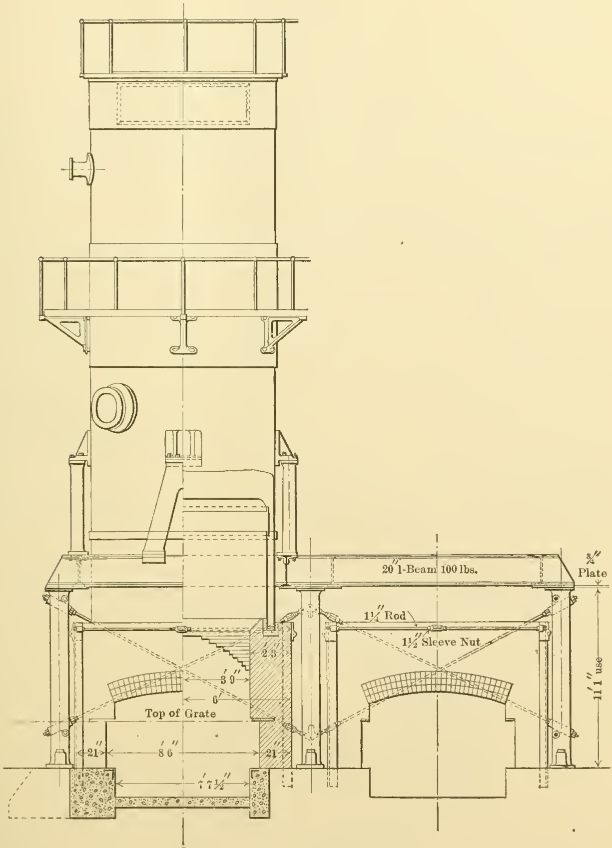


Fig. 2 Sectional Elevation of Furnace of the Author's Fire-tube Boiler

discussion, it should be remembered that it was good, only not as good as is sometimes the case.

5 Mr. Parker states that the tubes leaked for the reason that they were set close to the grate and were therefore subjected to wide ranges

of temperature. This is true if we consider the closing of many of the tubes by clinker and the consequent overheating of those that were not closed.

6 I agree with Mr. Bement that some other kinds of stoker would probably not have precipitated the clinker on the tube ends, and this I stated in the paper.

7 Concerning the ability of the water to enter among the tubes, there are many large vertical boilers, some nearly as large as the one described, that have far less space for the passage of water among the tubes, and no trouble results. I know of some that have only one wide space across the crown sheet, while mine have eight wide spaces entirely across, or sixteen reaching to the center.

8 I observe that Mr. Bement considers that the cause of the cessation of the leakage of the tubes of my boiler was the added surface of the water leg. I cannot feel that this is so. It is inconceivable to me that the heat near the center of the furnace should be sensibly reduced thereby. Moreover the absence of the clinker after the change seems to me ample cause of the improvement, for, as I have stated in the paper, a large proportion of the tubes were stopped up, and those that were in service must have been overheated. I think that if the boilers had been raised without adding to the water leg the trouble would have ceased.

9 Whatever the cause of the leakage may have been, I find on

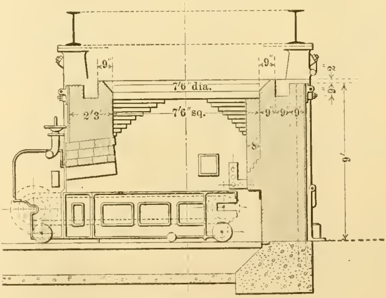


Fig 3 Section of Furnace of the Boiler Shown on page 279

January 17, 1910, the date of writing, that the tubes are not leaking, nor have they leaked since August 31, 1908, in the case of one boiler, and February 25, 1909, in the other, each boiler having been worked constantly to about 1000 boiler horsepower.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A.I.E.E. and A.I.M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

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Views and Description of Lake Cheesman. The Bulwark of Denver's Water Supply.

Welding and Cutting Metals by Aid of Gases or Electricity. By L. A. Groth. *New Yokr, Van Nostrand Co., 1909.*

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Fuel Tests With House-Heating Boilers. University of Illinois, Engineering Experiment Station. Bulletin No. 31. By J. M. Snodgrass. *Urbana, Ill., 1909.*

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U. S. Steam Engineering, Bureau of. Annual Report. 1909. *Washington, 1909.*

TRADE CATALOGUES

American Radiator Company, *Chicago, Ill.* Stock list of boilers, radiators, etc., 283 pp.; The Houses Successful, 40 pp.; Ideal Heating, 46 pp.; Results Successful, 20 pp.; Ideal boilers, 32 pp.; Vento cast-iron, hot-blast heaters, 48 pp.; Ideal round boilers, 32 pp.; Ideal sectional boilers, 32 pp.

Newman Clock Comapny, *Chicago, Ill.* Testimonials concerning the watchmen's portable clok, 9 pp.

Niles-Bement-Pond Company, *New York, N. Y.* Pond rigid turret lathe, 44 pp.

Sanders, Rehders & Company, Ltd., *London, England.* Sarco patent gas volume recorder, 4 pp.; Recording and indicating steam meters, 4 pp.; Fuel calorimeters, 4 pp.; Patent reversion recorder, 2 pp.; Recording draught gauge, 4 pp.

Underfeed Stoker Company of America, *Chicago, Ill.* Publicity Magazine, December 1909, concerning the Jones Stoker, 16 pp.

Wisconsin Engine Company, *Corliss, Wis.* Bulletin C–4. Heavy Duty Corliss Engines, belted type, 24 pp.

UNITED ENGINEERING SOCIETY

Index to Economic Material in Documents of Maine, 1820–1904; Massachusetts, New Hampshire, New York, Rhode Island, Vermont, 1789–1904. By A. R. Hasse. *Washington, 1907-1908.*

Manufacturers' Record. Annual Blue-book of Southern Progress, 1909. *Baltimore, 1909.* Gift of Manufacturers' Record.

Illustrations of Concrete Steel Arch Bridges. Gift of Concrete Steel Engineering Company.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

08 A company in the Middle West manufacturing moderately heavy machinery has a vacancy for an expert mechanical designer. The position will require a man of considerable experience in the designing of power machinery, familiar with steam and compressed air, and the application of electric motors. Must be capable of submitting original designs to meet conditions. Give experience fully, salary expected, and quote references. Location, Middle West.

09 Mechanical engineer, familiar with the designing and building of steam shovels. Location, Toronto, Canada.

MEN AVAILABLE

14 Technical graduate, experienced in several varied lines of industry, holding executive positions of responsibility during the last eight or nine years, desires to become associated in position of trust with good manufacturing concern, preferably located in the East or Middle West. Best of references.

15 Member, graduate Stevens Institute, eighteen years experience in design and construction of power plants and special machinery; competent to prepare plans, specifications and estimates; desires position with first-class firm of consulting engineers or manufacturing concern.

16 Graduate electrical and mechanical engineer, thirteen years practical experience in testing, inspection and construction work; past five years in charge electrical department and power plant of industrial establishment; executive ability and excellent references; desires to change to a broader field. Qualified for assistant to consulting engineer, assistant superintendent of manufacturing plant or assistant manager. Salary $2500.

17 Stevens graduate '97, extensive shop and drawing room experience, including steel, reinforced concrete, power house and conveying installations. New York city preferred.

18 Associate, experienced in design and installation of mechanical equipment of power stations, railway and industrial buildings, desires position in Middle West; competent executive in field or drafting room. Salary $200 per month, or on percentage basis with consulting engineers.

19 General manager, or assistant, graduate M. E., at present holding similar position, would like to make change; ten years practical experience; good executive ability, best of references.

20 Member, thoroughly experienced in the design of large gas engines for all services; desires position as chief engineer with company building this class of machinery or with a company desiring to enter the field, preferably the latter.

21 Junior, age twenty-nine, technical graduate, seven years experience shop, foundry, drawing room and office: desires to make a change. Compressed air, pumping machinery, or similar line preferred.

22 Junior member, technical graduate, nine years experience in drafting, construction and office work with engineers and contractors, in engineering departments of industrial companies; wishes to make change after May first. Prefer position with firm of engineers and contractors or with industrial company.

23 Student member, graduating Cornell University June 1910, desires position with engineering concern in New York city or thereabouts. Salary no object. Can furnish highest references.

24 Graduate of M.I.T., in electrical and mechanical engineering; experience in design and construction of machinery and buildings; development of systems and organization; making of reports, compilation of data, etc.

COMING MEETINGS

February-March

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the Editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN ASSOCIATION OF RAILROAD SUPERINTENDENTS
March 18, Chicago. Secy., O. G. Fetter.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
February 11, monthly meeting, 29 W. 39th St., New York. Paper: A Modern Automatic Telephone Apparatus, W. Lee Campbell. Secy., R. W. Pope.

AMERICAN INSTITUTE OF MINING ENGINEERS
March 1-5, Spring meeting, Hotel Shanley, Pittsburg, Pa. Secy., R. W. Raymond, 29 W. 39th St., New York.

AMERICAN MATHEMATICAL SOCIETY
February 26, New York and San Francisco sections. Secy., F. N. Cole, 501 W. 116th St., New York.

AMERICAN RAILWAY ENGINEERING ASSOCIATION
March 14-17, Chicago. Secy., E. H. Field, Monadnock Bldg.

AMERICAN SOCIETY OF CIVIL ENGINEERS
February 2, 16, 220 W. 57th St., New York, 8:30 p.m. Papers: Underpinning the Cambridge Building, New York City, by T. K. Thomson; Effect of Alkali on Concrete, by G. G. Anderson. Secy., C. W. Hunt.

AMERICAN SOCIETY OF ENGINEERING CONTRACTORS
February 24-26, annual meeting, Chicago, Ill. Secy., Daniel J. Haner, Park Row Bldg., New York.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
February 8, 29 W. 39th St., New York. February 16, City Club, Boston, May 31-June 3, Spring Meeting, Altantic City, N. J. July 26-29, joint meeting with Institution of Mechanical Engineers, Birmingham, England. Secy., Calvin W. Rice, 29 W. 39th St.

ASSOCIATION OF ONTARIO LAND SURVEYORS
February 22-24, annual meeting. Secy., Killaly Gamble, 703 Temple Bldg., Toronto.

BOSTON SOCIETY OF ARCHITECTS
February 1, Parker House, Boston, Mass. Dinner in the Crystal Room at 6.30 p. m. Secy., Edwin J. Lewis, Jr.

CANADIAN FORESTRY ASSOCIATION
March 10-11, Fredericton, N. B. Secy., Jas. Lawler, 11 Queen's Park, Toronto, Ont.

CANADIAN MINING INSTITUTE
March 2-4, annual meeting, Toronto, Ont. Secy., H. Mortimer-Lamb, Windsor Hotel, Montreal.

CONNECTICUT SOCIETY OF CIVIL ENGINEERS
February 8, annual meeting, New Haven, Conn. Secy., J. Frederick Jackson, Box 1304, New Haven, Conn.

ENGINEERING SOCIETY OF WISCONSIN
February 23-25, Milwaukee, Wis. Secy., W. G. Kirchoffer, 31 Vroman Bldg., Madison.

ENGINEERS CLUB OF PHILADELPHIA
February 5, annual meeting, 1317 Spruce St. Secy., W. P. Taylor.

INSTITUTION OF MECHANICAL ENGINEERS
February 18, Institution House, Storey's Gate, St. James' Park, Westminster, S. W., London, England. Secy., Edgar Worthington.

IOWA ASSOCIATION CEMENT USERS
March 9-11, Cedar Rapids. Secy., Ira Williams, Ames.

IOWA ENGINEERING SOCIETY
February 16-17, Cedar Rapids. Secy., A. H. Ford, Iowa City.

MINNESOTA ELECTRIC ASSOCIATION
March, St. Paul. Secy., B. W. Cowperthwait.

NATIONAL ASSOCIATION OF CEMENT USERS
February 21-26, annual convention, Chicago, Ill. Pres., Richard L. Humphrey, Harrison Bldg., Philadelphia, Pa.

NEBRASKA CEMENT USERS ASSOCIATION
February 1-4, Lincoln. Secy., Peter Palmer, Oakland.

NEW ENGLAND ASSOCIATION OF GAS ENGINEERS
February 16, 17, annual meeting, Boston, Mass. Secy., N. W. Gifford, 26 Central Sq., East Boston, Mass.

NEW ENGLAND RAILROAD CLUB
March 8, annual meeting, Boston, Mass. Secy., George H. Frazier, 10 Oliver St.

NEW ENGLAND STREET RAILWAY CLUB
March 24, annual meeting, Boston, Mass. Secy., J. J. Lane, 12 Pearl St.

NEW ENGLAND WATERWORKS ASSOCIATION
February 9, Hotel Brunswick, Copley Sq., Boston. Papers: Depreciation, L. G. Powers; The Purchase of Coal on Efficiency Basis, A. O. Doane.

NORTHWESTERN CEMENT PRODUCTS ASSOCIATION
February 18-21, annual meeting, Chicago, Ill. Chairman notification committee, O. U. Miracle, Minneapolis, Minn.

PACIFIC COAST ELECTRIC AUTOMOBILE ASSOCIATION
February, Oakland, Cal. Secy., J. T. Halloran, 604 Mission St., San Francisco.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS
February 15, West Hall of the Rhode Island School of Design, 8 p. m. Paper: The Bliss-Levitt Torpedo, Samuel Aronson and Chas. Gabriel.

RAILWAY SIGNAL ASSOCIATION
March 14, Chicago. Secy., C. C. Rosenberg, Bethlehem, Pa.

SCRANTON ENGINEERS CLUB
February 3, annual dinner, Club Rooms. Secy., A. B. Dunning.

SOUTHERN GAS ASSOCIATION

February 16, Chattanooga, Tenn. Secy., James Ferrier, Rome, Ga.

STEVENS ENGINEERING SOCIETY

February 8, 15, 21, Hoboken, N. J. Papers: Pavements for City Streets, Samuel Whinery, Mem. Am. Soc. M. E.; Power Plant Economies, D. S. Jacobus, Mem. Am. Soc. M. E.; The Engineer as a Manager, H. L. Gantt, Mem. Am. Soc. M. E. Secy., R. H. Upson.

UNIVERSITY OF CINCINNATI, Student Branch, AM. SOC. M. E.

February 18, regular meeting. Paper: Milling Machines and their Uses, C. S. Gingrich, Jun. Am. Soc. M. E. Secy., P. G. Haines.

MEETING IN THE ENGINEERING SOCIETIES BUILDING

Meetings of All Kinds

Date	Society	Secretary	Time
February			
2	Wireless Institute	S. L. Williams	7.30
3	Blue Room Engineering Society	W. D. Sprague	8.00
5	Amer. Soc. Hungarian Engrs. and Archs	Z. de Németh	8.30
8	The American Society of Mechanical Engrs	Calvin W. Rice	8.15
10	Illuminating Engineering Society	P. S. Millar	8.00
11	American Institute Electrical Engineers	R. W. Pope	8.00
15	New York Telephone Society	T. H. Lawrence	8.00
18	New York Railroad Club	H. D. Vought	8.15
23	Municipal Engineers of New York	C. D. Pollock	8.15
March			
2	Wireless Institute	S. L. Williams	7.30
3	Blue Room Engineering Society	W. D. Sprague	8.00
5	Amer. Soc. Hungarian Engrs. and Archs	Z. de Németh	8.30
8	The American Society of Mechanical Engrs	Calvin W. Rice	8.15
10	Illuminating Engineering Society	P. S. Millar	8.00
11	American Institute Electrical Engineers	R. W. Pope	8.00
15	New York Telephone Society	T. H. Lawrence	8.00
18	New York Railroad Club	H. D. Vought	8.15
23	Municipal Engineers of New York	C. D. Pollock	8.15

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Note—Numbers in parentheses indicate number of years the member is yet to serve.

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1909

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NOTE—Numbers in parentheses indicate number of years the member is yet to serve.

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STUDENT BRANCH	AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	....	C. F. Hirshfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	C. F. Gebhardt	N. J. Boughton	M. C. Shedd
Leland Stanford, Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	E. A. Rogers	H. C. Warren
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. A. Kirk	J. R. Jackson
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	H. S. Coleman	John Garver
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	W. F. Colman	S. G. Wood
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York	November 9	....	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Fredk. A. Dewey	A. P. Truette
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	W. H. Mantgomery	P. G. Haines
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	R. N. Trane	G. A. Glick
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. E. Dudley	F. T. Kennedy
Univ. of Nebraska, Lincoln, Neb.	December 7	C. R. Richards	....	....

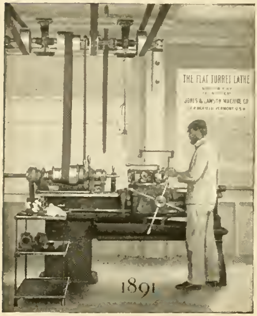
ADVERTISING SUPPLEMENT

SECTION 1

Machine Shop Equipment

HARTNESS FLAT TURRET LATHE

Pages from the book of the Hartness Flat Turret Lathe
Copies of book cheerfully mailed on request



THE book contains a carefully prepared description of the Flat Turret Lathe followed by extracts from our previous publication "Evolution of the Machine Shop."

In order to avoid an abstract and wearisome description frequent reference has been made to other machine tools, but throughout the whole it is hoped there will be found a spirit of fairness and an exactness of utterance.

Our aim has been to avoid the discourtesy of making extravagant or superficial statements to those who are seeking information of a definite character.

Since the introduction of the Flat Turret Lathe in 1891, it has had a steadily increasing sale and a corresponding development.

For many years our entire plant has been exclusively devoted to the manufacture of this lathe and its equipment of tools, and we have enjoyed the reputation of being the only machine tool builder making only one machine and that in only one size.

We now offer the machine in two sizes for both bar and chucking work. An important change in its appearance was made in 1904 when the new cross sliding head was introduced, but the lathe was the same old machine taking on an outward shape that conformed to the natural growth and development.

Springfield, Vt., U. S. A. **Jones & Lamson**

Germany, Holland, Belgium, Switzerland, Austria-Hungary,
M. Koyemann, Charlottenstrasse 112, Düsseldorf, Germany.

HARTNESS FLAT TURRET LATHE

OUR METHOD OF SELLING

WE sell only to the user, and have no other agents or offices than those given on page 3 of our catalogue for the various countries name.

In the United States and Great Britain we have our own traveling representatives whose time is wholly devoted to the Flat Turret Lathe.

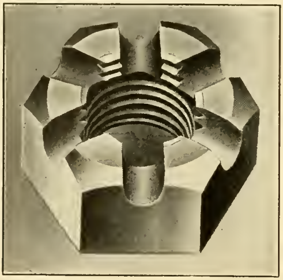
A personal inspection of your work by a specialist thoroughly versed in this branch of lathe work may be had within one or two days by wiring us, provided your plant is located in the British Isles or in the manufacturing States bordering on or east of the Mississippi and north of North Carolina and Tennessee.

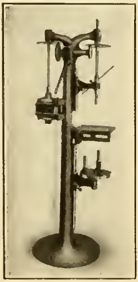
Since we have our representatives in this field, you are placed under no obligations to us by making a request for such an inspection and report or proposition.

There can be no uncertainty about price, for we quote a fixed price only, and any one may know our prices.

We make free deliveries to nearly all points, and send without charge an operator to instruct your workman in the use of the machine, thus relieving you of all responsibility, except that you agree to accept and pay for the machine and equipment if we fulfil our guarantee.

The Flat Turret Lathe is made by no other maker in United States. There are nearly 5000 now running; therefore, there is no uncertainty about this being *the* machine. It is either called the Hartness Flat Turret or the Jones & Lamson Flat Turret, but it is always the "Flat Turret." The present machine is protected by many American, British and German patents.





YEAR BOOKS

The Society wishes to have a file of year books or catalogues complete since its formation. Will members who have any of the following numbers either send them to the Society or correspond with the Secretary

No. 2, 1881	No. 6, 1885	No. 13, 1892, July
No. 3, 1882	No. 7, 1886	No. 14, 1893, January
No. 5, 1884	No. 12, 1891, July	No. 14, 1893, July

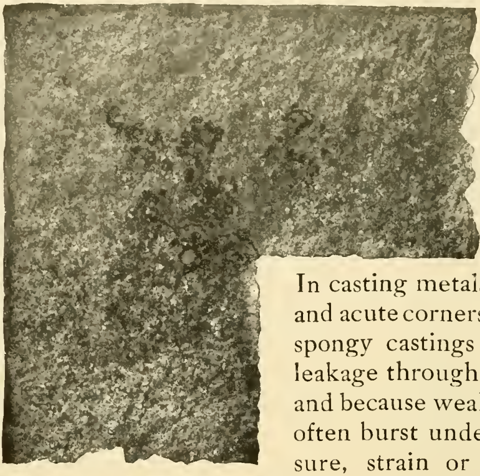
Also the 1903 edition of the Pocket List of Members

The American Society of Mechanical Engineers
29 West 39th Street, New York

ADVERTISING SUPPLEMENT

SECTION 2

Power Plant Equipment



This is photograph of cast iron section *magnified four times original size*, showing uneven grain metal, some porous spots, spongy corner, and cracks common to a casting with square corners.

In casting metals, straight lines and acute corners produce open, spongy castings susceptible to leakage through porous bodies, and because weak in spots, they often burst under sudden pressure, strain or accidental jar.

Inspect sectional view Nelson Gate Valve shown on this page and note absence of square corners.

In Nelson design, these weak and porous spots are avoided, model being built on curves that allow metals, when cast, to flow freely and set uniformly and dense, making castings both non porous and unusually strong.

Nelson Valve Company
PHILADELPHIA

New York
Chicago
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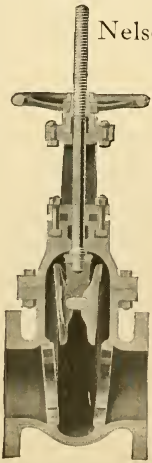
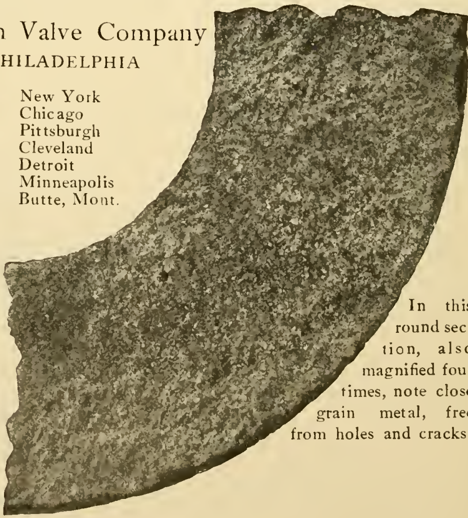
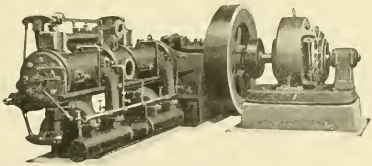
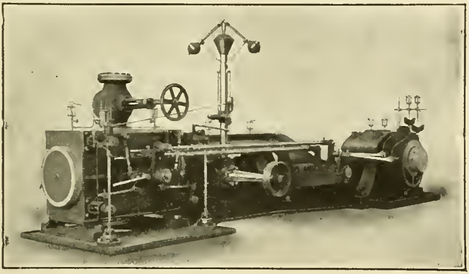


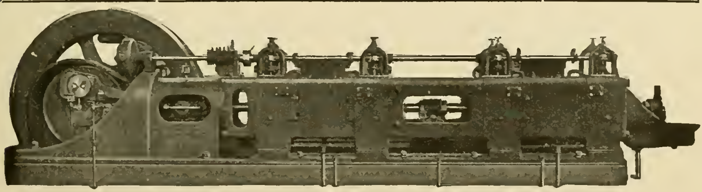
Internal view of Nelson Medium Iron Body Gate Valve showing round design.



In this round section, also magnified four times, note close grain metal, free from holes and cracks.







Superheated Steam

Papers read before

The American Society of Mechanical Engineers
from 1890 to 1908

The Society has a limited number of copies of papers on Superheated Steam which have been presented before it. Orders will be filled until the supply is exhausted.

No.		Price to Members	Non-Members
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689	Superheated Steam, Facts, Data and Principles, R. H. Thurston	25	50
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905	The Practical Application of Superheated Steam, Geo. A. Hutchinson	15	30
906	Superheated Steam, Ernest H. Foster	5	10
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1156	Superheated Steam on Locomotives, H. H. Vaughan	10	20
1158	Materials for the Control of Superheated Steam, M. W. Kellogg	5	10
1178	The Specific Heat of Superheated Steam, C.C. Thomas	30	60
1179	Designs of Engines for the Use of Highly Superheated Steam, M. E. R. Toltz	10	20
	(WILL BE READY SHORTLY)		
1196	Thermal Properties of Superheated Steam, R. C. H. Heck	15	30
1211	A Method of Obtaining Ratios of the Specific Heat of Vapors, A. R. Dodge	10	20
1212	The Total Heat of Saturated Steam, H. N. Davis	15	30
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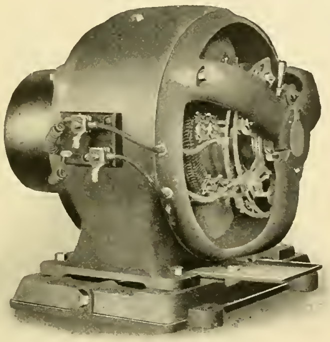

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Frames 20 to 90

The Motors that give Satisfactory Service

Sprague Electric Motors are made in sizes ranging from 1-20 h.p. to 500 h.p. and have a world wide reputation for excellence due to their superior design and construction.

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DIRECT CURRENT

FOR LIGHT AND POWER

have been the standard for years. They have good regulation, high efficiency and excellent commutation on overloads without shifting the brushes. Besides these advantages, they possess compactness, rigidity, durability and an attractive appearance which places them foremost among modern types of electrical generating machinery. Sizes range from $\frac{1}{4}$ kw. to 750 kw.

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One of the largest collections of Engineering literature in the world is THE ENGINEERING LIBRARY in the Engineering Societies Building, 29 West 39th Street, New York.

It comprises 50,000 volumes, including many rare and valuable reference works not readily accessible elsewhere. There are 450 current technical journals and magazines. All the foreign and domestic technical periodicals are received, as well as the proceedings of the various engineering societies of the world.

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The Engineering Societies Building

29 West 39th Street, New York

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Power Transmission

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American Engineer, Chicago. Vol. 1. 1880.
American Gas Light Association. Vol. 1. Prior to 1875.
American Machinist. Vols. 1 and 2.
American Society of Naval Engineers. Vol. 1. 1889.
Mechanical Engineers, N. Y. Vols. 1-4. 1881-1882.
Scientific American. First Series. Vol. 1.
Die Gasmotorentechnick. Vols. 1-5, 6. Nos. 1-9.
Le Génie Civil. Vols. 1-23. 1880-1892.
Glaser's Annalen für Gewerbe u. Bauwesen. Vols. 1-7. 1865-1889.
Verein Deutscher Ingenieure. Vols. 1-7. 1857-63.
Der Schiffbau. Vols. 1-8.

The American Society of Mechanical Engineers
29 West 39th Street, New York

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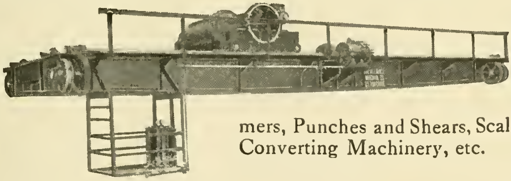

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ELECTRIC AND HAND POWER
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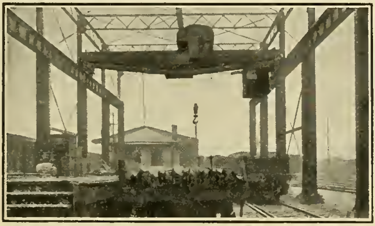

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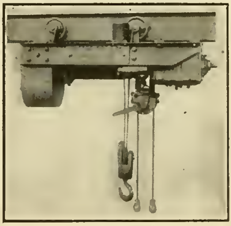

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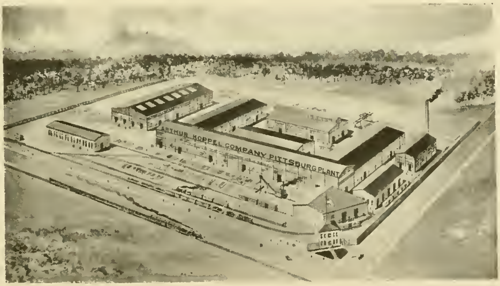
should be designed to accommodate immediate increase of output, *and also* to provide for future extensions of buildings and equipment at a minimum of cost and a maximum of efficiency.

The Problems Encountered

in the laying out of such a plant, its construction, equipment and initial operation, are most quickly, efficiently and economically solved by employing an organization of skillful and experienced engineers.



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TROY, N. Y.

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Manufacturers of the Franklin Water-Tube Boiler. Built entirely of wrought steel. Large grate service, steam space and forcing capacity.

WATER-TUBE
BOILER

HARRISBURG FOUNDRY & MACHINE WORKS

HARRISBURG, PA.

Manufacturers of Fleming-Harrisburg Horizontal Engines, Corliss and Single Valve, Simple, Tandem and Cross Compound.

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THE

JOURNAL

THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

MARCH 1910

MEETINGS OF THE SOCIETY: NEW YORK, MARCH 8; BOSTON, MARCH 11; SPRING MEETING, ATLANTIC CITY, MAY 31 TO JUNE 3. MEETING IN ENGLAND, JULY 26 TO 29.

MARCH 1910 VOL. 32 No. 3

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CONTENTS

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THE JOURNAL is published by The American Society of Mechanical Engineers twelve times a year, monthly except in July and August, semi-monthly in October and November.

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CONTENTS—Continued

The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 MARCH 1910 NUMBER 3

THE New York monthly meeting for March will be held in the Engineering Societies Building, Tuesday evening, March 8, the American Institute of Electrical Engineers participating. The paper will be by H. G. Stott, Mem.Am.Soc.M.E., Superintendent of Motive Power, Interborough Rapid Transit Company, New York, and J. S. Piggott, on Tests of a 15,000-kw. Steam-Engine-Turbine Unit.

The paper relates to the installation of low-pressure turbines at the 59th Street station of the Interborough Rapid Transit Company, New York, and presents a discussion of the most important development in steam engineering since the introduction of the steam turbine. The station is equipped with engines of the Manhattan type, which are double engines having 42 in. horizontal high-pressure cylinders and 86 in. vertical low pressure cylinders with a 5000-kw. generator. The generator is capable of carrying a load of 8000 kw. continuously but the best economy of the engine is obtained at about 5000 kw. and a low-pressure turbine was added to operate on the exhaust steam from the engine, with a view to increasing the capacity of the unit and at the same time improving the efficiency. Two turbines have been installed and the third is in process of installation. By the addition of the turbine the engine can be run to the full capacity of the generator to which is added the current from the turbo-generator, making a total output of 15,000 kw. The paper is published in this issue and gives complete details of the results of tests. An extended discussion is expected by prominent engineers connected with central stations.

BOSTON MEETING, MARCH 11

The next monthly meeting in Boston will be held Friday evening, March 11 in the auditorium of the Edison Electric Illuminating Company. The Boston Section of the American Institute of Electrical Engineers will cooperate in the meeting, and it is expected also that the Boston Society of Civil Engineers will join with these organizations. The paper will be by M. W. Alexander, member Am.Soc.M. E., who has been so long identified with the educational work and training of apprentices and employees at the works of the General Electric Company, West Lynn, Mass. The subject of the paper is The Training of Men, A Necessary Part of the Modern Factory System. This paper was published in the January number of the Journal.

MEETING IN BOSTON, FEBRUARY 16, 1910

A meeting of the American Institute of Electrical Engineers, The American Society of Mechanical Engineers coöperating, was held in the auditorium of the City Club of Boston, February 16. At an informal dinner held at the club preceding the meeting, 250 members and guests were present, while about 500 attended the professional session. The meeting was called to order at 8 o'clock by Prof. Dugald C. Jackson, Mem.Am.Soc.M.E., chairman of the Boston section of the American Institute of Electrical Engineers. David B. Rushmore, Mem.Am.Soc.M.E., chairman of the Industrial Power Committee of the Institute was called to the chair and presided during the presentation of the following papers: The Applicability of Electrical Power to Industrial Establishments, by Dugald C. Jackson, Mem. Am.Soc.M E ; Central Stations vs. Isolated Plants for Textile Mills, by Charles T. Main, Mem.Am.Soc.M.E.; The Supply of Electrical Power for Industrial Establishments from Central Stations, by R. S. Hale, Mem.Am.Soc.M.E.; Illumination for Industrial Plants, by G. H. Stickney; The Requirements for an Induction Motor from the User's point of View, by Walter S. Nye. The discussion was principally upon Mr. Main's introductory paper, Central Stations vs. Isolated Plants for Textile Mills. The meeting was successful in every way, and an indication of the wisdom of engineers in all branches getting together to discuss topics of general interest.

YEAR BOOK FOR 1910

The Year Book of the Society for the year 1910 is now being distributed to the membership. It is issued in new form, designed to

embody the advantages both of the Year Book, as previously issued, and of the Pocket List, which has formerly been published in August of each year.

The Year Book originally had two lists of members, one alphabetical, containing particulars regarding the business, the membership in the Society, and the business and home addresses of each member; and a geographical list, containing only the names of the members. The Pocket List was arranged with the geographical list containing the details regarding the members and an alphabetical list giving only the names, without other information.

In its new form, the Year Book contains a complete alphabetical list as before, and in addition, a geographical list with sufficient information regarding the business title and address of each member to make the list useful to one traveling or to those who desire to correspond with members in any particular city or connected with a particular firm.

The book is issued in a size that is convenient either for the desk or to carry in traveling and is bound in substantial cloth-covered board covers.

STUDENT BRANCHES

UNIVERSITY OF KANSAS

At the first annual meeting on December 9, 1909, papers were presented by S. M. Manley, Mem.Am.Soc.M.E., on A Ten Hour Log of a Boiler Plant; John D. Garver, Student, 1909, on The South American Machinery Market; Louis Bendit, Mem.Am.Soc.M.E., on Economical Power Development; P. F. Walker, Mem.Am.Soc. M.E., on Testing Lubricating Oils; and Paul M. Chamberlain, Mem.Am.Soc.M.E., on Increased Efficiency in the Boiler Room. An opportunity was given to visit plants and buildings in connection with the meeting and the business sessions were followed by a dinner to members and guests. Mr. Chamberlain in his paper, now on file in the headquarters of the Society in New York, discussed at length important features entering into the design and operation of boilers and furnaces, present costs of apparatus and of power plants complete, and the cost to operate coal and ash handling machinery. The organization holds weekly meetings at which technical papers and magazine reports are presented by students, as well as by occasional invited speakers.

PENNSYLVANIA STATE COLLEGE

The first regular meeting of the Pennsylvania State College Student Section as held on January 14, with Aeronautics as the topic for discussion. Prof. Arthur J. Wood, Mem.Am.Soc.M.E., exhibited a small model biplane which he had constructed. At the February meeting Power Plant Accessories were considered.

BROOKLYN POLYTECHNIC INSTITUTE

The student branch of the Brooklyn Polytechnic Institute is preparing to publish an annual, to contain papers by speakers, professors and students. At the January meeting Leon B. Lent, Mem. Am.Soc.M.E., delivered an illustrated lecture on Modern Gas Engines.

SPRING MEETING, ATLANTIC CITY

The Spring Meeting of the Society will be held at Atlantic City, May 31 to June 3 inclusive, with headquarters at the Marlborough-Blenheim. There will be the usual professional sessions, announcement of which will be made later, and on Wednesday evening, June 1, honorary membership will be conferred upon Rear-Admiral Geo. Wallace Melville, U. S. Navy, Retired, and Past-President of the Society.

RAILROAD TRANSPORTATION NOTICE

Arrangements for hotel, transportation and Pullman car accommo dations should be made personally.

Special concessions have been secured for members and guests attending the Spring Meeting in Atlantic City, May 31 to June 3, 1910.

The special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below. Read item *g*.

a Buy your ticket at full fare for the going journey, between May 27 and June 2 inclusive. At the same time request a certificate, *not a receipt*. This ticket and certificate should be secured at least half an hour before the departure of the train.

b Certificates are not kept at all stations. Ask your station agent whether he has certificates and through tickets. If not, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point, and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to S. Edgar Whitaker, office manager at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after June 3.

d An agent of the Trunk Line Association will validate certificates, June 1, 2, 3. No refund of fare will be made on account of failure to have certificate validated.

e One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

f If certificate is validated, a return ticket to destination can be purchased, up to June 8, on the same route over which the purchaser came, at three-fifths the rate.

g Members and guests from New York City should buy the regular round trip tickets at $5 and show the return portion to Mr. Whitaker or the validating agent.

The special rate is granted only for the following.:

The Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

The Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

The New England Passenger Association except via N. Y. O. & W. R. R. and Eastern Steamship Co. The Rutland R. R. participates in fares reading via its road:

Maine, New Hampshire, Vermont, Massachusettes, Rhode Island and Connecticut.

The Western Passenger Association offer revised one-way fares, on the basis of two cents per mile, to Chicago, Peoria and St. Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs:

North Dakota, South Dakota, Nebraska, Kansas, Colorado, east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri, north of a line through Kansas, Jefferson City and St. Louis; Illinois, north of a line from Chicago through Peoria to Keokuk.

JOINT MEETING WITH THE INSTITUTION OF MECHANICAL ENGINEERS

BIRMINGHAM AND LONDON, ENGLAND, JULY 26-29, 1910

In response to the invitation of The Institution of Mechanical Engineers to the Joint Meeting of the Institution of Mechanical Engineers and The American Society of Mechanical Engineers to be held in Birmingham and London in July, 117 members and ladies have already engaged passage on the official steamship Celtic, while 205 members, with 155 ladies, have signified their intention of going.

The following tentative program has been outlined by a Committee of the Council of The Institution of Mechanical Engineers.

Tuesday, July 26, 1910. Birmingham.

Morning, 10 a.m. Reception in Birmingham. Professional Session.

Afternoon. Visits to Works, and to Stratford, etc.

Evening. Garden Fête.

Wednesday, July 27, 1910. Birmingham.

Morning. Professional Session.

Afternoon. Visits to Works, etc.

Evening. Reception in Council House, by invitation of the Right Hon. the Lord Mayor of Birmingham.

Thursday, July 28, 1910.

Whole-day Excursions; arriving in London in time to reach hotels and attend late Conversazione at the Institution.

Friday, July 29, 1910. London.

Morning. Professional Session at the Institution of Civil Engineers.

Afternoon. Visits and social functions.

Evening. The Institution Dinner. Including Ladies.

Saturday, July 30, 1910, London.

Whole-day excursions, Windsor and Henley (by invitation).
Evening. Reception at the Japanese-British Exhibition. By invitation.

The Committee are of opinion that members of the American Society will prefer to make their own arrangements for the time between the arrival in Liverpool and the opening of the Meeting in Birmingham at 10 o'clock on Tuesday, as Chester and other places of interest are in the immediate vicinity.

With regard to hotels in Liverpool, the Adelphi, Exchange and Great Western are considered the three principal hotels. Southport ($18\frac{1}{2}$ miles away) is now almost a suburb of Liverpool on account of the frequent service of electric trains, and is a pleasant seaside resort. A list of hotels in Birmingham and neighborhood will be published later.

INVITATION FROM INSTITUTION OF CIVIL ENGINEERS

The following letter of invitation has been received from the Institution of Civil Engineers and acknowledged with appreciation by the Council of The American Society of Mechanical Engineers:

THE INSTITUTION OF CIVIL ENGINEERS
GREAT GEORGE ST., WESTMINSTER, S. W.
11 January, 1910.

Calvin W. Rice, Esq., Secretary,
The American Society of Mechanical Engineers,
29 West Thirty-ninth Street, New York

My Dear Sir,

Hearing from the Institution of Mechanical Engineers that a joint meeting between that Institution and The American Society of Mechanical Engineers is to be held here in July next, the Council of this Institution, at a meeting held today, desired me to request you to be so good as to convey to the members of The American Society of Mechanical Engineers a very cordial invitation to them to avail themselves, during the period of the meeting, of the accommodation which the rooms of this Institution can afford.

I am
Yours faithfully,
J. H. T. TUDSBERY,
Secretary.

REPORTS

MEETING OF THE COUNCIL

At a meeting of the Council, held on Tuesday, February 8, 1910, in the rooms of the Society, there were present Messrs. Abbott, Baker, Bancroft, Bond, Carpenter, Gantt, Hartness, Humphreys, Hutton, Meier, Moultrop, Reist, Smith, Stott, Waitt and the Secretary. Regrets were received from the President and from W. F. M. Goss, Vice-President. On motion Dr. Humphreys acted as Chairman.

The minutes of the meeting of January 11 were read and approved.

The Secretary reported the death of Charles Batchelor.

The resignations of R. Carter Beverley, J. S. Avery, Jr., and F. C. Slade were accepted, and announcement of the lapsing of the membership of the following was made by the Secretary: E. E. Barnard, F. E. Bradenbaugh, Jas. Breen, J. M. Briggs, E. D. Clarage, J. C. Dodwell, W. F. Donovan, L. H. Gardner, J. N. Gregory, G. O. Hodge, Nathaniel Lombard, C. F. Meissner, E. E. Miller, Jas. Naughton, H. E. Newell, H. W. Pudan, W. B. Reed, F. A. Schroeder, E. O. Spillman, G. W. Steward, F. P. Thorp, A. A. Thresher, and A. J. Weichardt.

The Executive Committee reported that 49 members had reserved passage on the Celtic, the official steamship for the Joint Meeting in England.

Voted: That the Meetings Committee, in providing for the professional sessions, including papers and discussions, for the Joint Meeting, will entirely fulfill its duty.

The report of F. M. Whyte, Honorary Vice-President, to the National Civic Federation, was received and placed in file.

Voted: That the Secretary be directed to reply to the request for coöperation with the editors of the proposed American Year Book that the Society will be pleased to lend assistance by giving information but can take no official part directly or indirectly in the publication.

Voted: That the invitation of the Institution of Civil Engineers be accepted with thanks, whereby the courtesies of the rooms of

the Institution are extended to the members of The American Society of Mechanical Engineers attending the joint meeting with the Institution of Mechanical Engineers in July 1910.

The election of Rear-Admiral George W. Melville to Honorary Membership by unanimous ballot, was announced.

Resolved: That the checks from the Treasurer be made payable to the order of the cashier and his bond be equal to the maximum amount of funds subject to his control.

Mr. Waitt, Chairman of the Finance Committee, presented a further report regarding the proposed amendments to B18 and C18 that had been referred to the Finance Committee for recommendation and report to the Council.

Voted: That the proposed amendments with the report of the Finance Committee be referred to the Committee on Constitution and By-Laws for report to the Council.

Voted: To approve the application for a student branch at the University of Maine, Orono, Me.

Voted: To approve the modifications of the standards, as approved by the Executive Committee and referred to them under the provisions of the By-Laws, January 21, 1910: general ledger, members card ledger, collection of dues, funds of the society, instructions on savings accounts, instructions on finance report, general information for office.

Notice was also given of proposed amendments to standards on instructions for paying bills, instructions on membership, committee work, election of members, classification of accounts, style sheet, cashier's funds, purchasing, etc.

On motion the meeting adjourned to March 8, 1910.

ABSTRACT OF REPORT OF LIBRARIAN

To the Library Committee:

Books and Pamphlets in the Library during the period July 1, 1908, to December 31, 1909, are listed in the accompanying table. During this time 1531 volumes, chiefly periodicals, have been bound at a cost of $1339.92.

BOOKS AND PAMPHLETS IN THE LIBRARY

	Accessions		Total in Library	
	Books	Pamphlets	Books	Pamphlets
A. S. M. E.	562	67	8,607	1406
A. I. M. E.	1176	2638	18,119	4542
A. I. E. E.	1573	1152	13,936	1248
United Engineering Societies	37	23	37	23
Total	3348	3880	40,699	7219

PERIODICALS

On July 1, 1908, there were 690 current periodicals in the joint libraries, 259 being duplicates, and on December 31, 1909, the number of periodicals regularly received, exclusive of duplicates, was 557.

Seventy-four of the duplicate sets were sold during 1909 at a net profit of $150.21. In addition $111.16 was received from the sale of various books and odd periodicals.

Researches and transcriptions have been made during the period to the amount of $31.

CIRCULATION OF BOOKS

Call cards were placed in commision on March 1, 1909 and the following table indicates the character of the books and periodicals consulted. This tabulation, however, represents only about a third of the circulation, as many people go directly to the shelves and do not ask for information.

Architecture	6
Bibliography	2
Biography	6
Chemical Technology	25
Chemistry	14
Civil Engineering	19
Description and Travel	6
Electrical Engineering	75
Electricity	33
Engineering	31
General Geology	83
Hydraulic Engineering	17
Mathematics	16
Marine Engineering	10
Mechanical Engineering	102
Metallurgy	65
Mining Engineering	52
Miscellaneous	7
Periodicals	111
Physics	21
Railroad Engineering	16
Railroad Engineering, Electric	17
Total	734

The attendance in the Library is shown in the following table:

LIBRARY ATTENDANCE

JANUARY 1908—DECEMBER 1909

1908	Day	Night	1909	Day	Night
January	541	148	January	485	250
February	439	241	February	533	254
March	417	203	March	536	280
April	403	210	April	529	217
May	400	196	May	462	221
June	419	136	June	484	196
July	441	....	July	472	....
August	362	....	August	472	....
September	392	125	September	434	220
October	381	180	October	471	238
November	435	200	November	479	223
December	520	441	December	545	301
Total	5151	2080	Total	5901	2402

Total for 1908: 7231. Total for 1909: 8303.

During 1909 the general reference section of the Engineering libraries has been strengthened by the addition of the following reference books:

Bartholomew's New Atlas of the World's Commerce.
Bouvier's Law Dictionary, 2 vols.
Calisch's Dictionary of the Dutch Language, 2 vols.
Cyclopedia of Building Trades, 6 vols.
Dietrich's Bibliographie der deutschen Zeitschriften Literatur.
Flügel's Universal German-English Dictionary, 3 vols.
Larousse's Dictionnaire Françaises, 22 vols.
Meyer's Grosses Konversation Lexikon, 20 vols.
Mullhouse's Italian Dictionary, 2 vols.
Rand & NcNally Business Atlas.
Michaelis's Portuguese-English Dictionary, 2 vols.
Webster's New International Dictionary.
Qui Etes-Vous?
New York Business Directory.
Wer Ist's?

This department is also equipped with:

The Annual Library Index, 1908 (popular engineering material arranged in classes).

The Engineering Index, which is arranged separately in binders by the following classes: civil engineering; electrical engineering; industrial economy; marine and naval engineering; mining and metallurgy; mechanical engineering; railway engineering; street and electric railways.

Engineering Digest.
Le Mois Scientifique et Industriel.

Technical Index.
Reader's Guide.
Poole's Index.
Technical Press Index.
Repertorium der technischen Journal Literatur (superseded in 1908 by Technische Auskunst, published by Bibliographical Institute of Berlin.
Stone & Webster's Current Literature.

There is also a card index of the literature in the engineering periodicals received by the Engineering Societies library. Many of these entries duplicate those of the engineering index, but the library data are available several weeks earlier than the monthly printed index.

The two front alcoves have been arranged to be of practical use to the general public. They possess more advantages than are usually permitted in any of the large public libraries.

To the present equipment will be added very soon:

a Indexes of periodicals and transactions of societies.
b All current foreign periodicals.
c Official patent publications of all countries.
d Lists of periodicals in other libraries.
e The undertaking of researches and translations at hourly rates.
f A bulletin board for new books, and coming meetings and congresses.

Respectfully submitted
L. E. Howard,
Librarian

UNITED ENGINEERING SOCIETY

REPORT OF TREASURER

To the Board of Trustees
United Engineering Society

I beg to submit herewith report of the treasurer as of December 31, 1909.

From the balance sheet submitted herewith it appears that our physical property, over and above the value of the building and our equity in the land, consists of building equipment amounting to \$16,767.72, and furniture and fixtures, \$2,921.20.

During the current year there have been added to the real estate equipment account a toilet room on the twelfth floor, at an expense

of $530, and furniture and fixtures representing an expenditure of $682.86, including telephone booths, stereopticon, tables, chairs, etc.

It will be noted that the principal of the mortgage on the land, held by Andrew Carnegie, Esq., and amounting originally to $540,000, has been reduced by payments from the land and building funds of the Societies to $223,000, correspondingly reducing the burden on the Founder Societies for payment of interest.

The gross operating expenses for the year were $35,845.92 or, excluding expenditures for building equipment, $530, and furniture and fixtures to the amount of $682.86, a net cost of operating the building for the year 1908 of $32,163.57, slightly in excess of 1908.

In accordance with the resolution of the board an appropriation of $5000 was made out of the surplus remaining from the year 1908 and this amount ($5,037.50) was invested in Baltimore & Ohio bonds, as an addition to the contingency and renewal fund, as provided for in the Founders' Agreement, bringing the reserve fund up to $10,268.75. It is recommended that a similar appropriation be made out of the available balance from this year's operations, leaving a surplus to be carried forward of $3,905.95.

Attention is called to the fact that we had on January 24, 1910, unoccupied floor space in the building equivalent in rental value to only 4 per cent of the total space availab e for assessment and a part of this small remaining space is under option, so that the only space available and unengaged is the room and ante-room occupied by the Trustees as Board Room, and even that is occasionally called upon for board meetings under assessment for outside parties. One of the Founder Societies is prepared to release one or two rooms for applications from Associates, otherwise the building may be deemed fully occupied.

Your attention is directed to the small number of times the auditorium has been occupied during the year, thirty times as against twenty-seven times in 1908, and the relatively small demand for the two assembly rooms on the fifth floor, occupied fifty-six times in 1909 as against sixty-eight times in 1908. During the past year the facilities of the building were enjoyed by fifty-two societies, Founders and Associates, as against thirty-four in the year 1908. The limited use made of the auditorium and of the assembly rooms on the fifth floor, the income therefrom barely covering their quota of the fixed charges, continues to be a problem in the economical administration of the building.

The chief librarian reports a total attendance during the year of

8303 as against 7231 in 1908, the day attendance showing an increase of 750 and the evening attendance of 322.

The assessments paid for the year by the Founder Societies occupying one entire floor were $6000 each, representing a total expenditure by each, including interest on its full principal of mortgage on the land, of $13,000, reduced in each case to the extent the Society may have paid off part of its mortgage share. As the associate societies are assessed approximately $10,000 for equivalent facilities, it will be seen that the Founder Societies are still carrying more than their proportion of the carrying charges for equivalent office space occupancy in the building.

Respectfully submitted,

(*Signed*) J. W. Lieb, Jr.,

Treasurer

UNITED ENGINEERING SOCIETY

Balance Sheet, January 1, 1910

ASSETS			
Real Estate, Land		$540,000.00	
Real Estate, Building		1,050,000.00	
Real Estate Equipment		16,767.72	
Furniture and Fixtures		2,921.20	
N. Y. City Bonds (cost) Reserve		5,231.25	
Balto. & Ohio Bonds (cost) Reserve		5,037.50	
Accounts Receivable		3,357.00	
Library United Engineering Society		29.05	
Library, adjustment account		30.56	
CASH			
Working Balance	$5,099.88		
For Reserve Fund	5,000.00		
Ways and Means Com	1,165.08	11,264.96	
Petty Cash		500.00	
		$1,635,139.24	
LIABILITIES			
Balance of Mortgage (Land) A.I.E.E		$54,000.00	
Balance of Mortgage, (Land) A. S. M. E.		81,000.00	
Balance of Mortgage, (Land) A.I.M.E		88,000.00	$223,000.00
A.I.E.E. Equity in Building			350,000.00
A.S.M.E. Equity in Building			350,000.00
A.I.M.E Equity in Building			350,000.00
A.I.E.E. Equity in Real Estate Equipment			3,346.61
A.S.M.E. Equity in Real Estate Equipment			3,346.62

A.I.M.E. Equity in Real Estate Equipment..................	3, 346.62
A.I.E.E. payments to date in liquidation of Mortgage on Land .	126,000.00
A.S.M.E. payments to date in liquidation of Mortgage on Land.	99,000.00
A.I.M.E. Payments to date in liquidation of Mortgage on Land.	92,000.00
Depreciation and Reserve Fund....	15,000.00
Ways and Means Committee, etc............................	1,165.08
Accounts Payable..	1,150.00
Balance Cash, Accounts Received, Furniture, etc.............	17,784.31
	$1,635,139.24

Statement of Receipts and Disbursements Year Ending December 31, 1909

Cash

RECEIPTS

Balance on hand January 1, 1909......................	$6,510.63
Account Reduction of Mortgage on Land...........	64,000.00
Account Interest on Mortgage......................	10,740.00
Assessment of Founder Societies....................	18,000.03
Assessment of Associates, Offices, Meetings..........	27,363.29
Library Acount....................................	5,109.27
Interest on Bonds.................................	225.00
	$131,948.22

DISBURSEMENTS

Account Reduction of Mortgage on Land.......	$64,000.00
Account Interest on Mortgage.................	10,740.00
Operating Expense, Cash Expenditures.........	30,445.39
Real Estate Equipment........................	530.00
Furniture and Fixtures........................	682.86
Library Account..............................	5,195.52
Bonds purchased (reserve)....................	5,037.50
Accounts Payable (from 1908).................	1,399.37
A.I.M.E. return of rentals for office	660.00
Insurance....................................	2,469.49
Library adjustment...........................	688.21
Balance on hand, January 1, 1910...............	10,099.88
	$131,948.22

Operating Income and Expenses Year Ending December 31, 1909

INCOME

Assessment Founders	$18,000.03	
Less A.I.M.E. refund..........	660.00	$17,340.03
Assessment Associates		16,746.00
Assessment Miscellaneous (Offices and meetings)		5,991.50
Telephone returns..............................		2,620.70
Miscellaneous charges to Societies..............		1,828.64
Interest.......................................		225.00
		$44,751.87

EXPENSES

Operating Expenses, gross	$32,163.57
Real Estate Equipment	530.00
Furniture & Fixtures	682.86
Reserve Fund	5,000.00
Insurance	2,469.49
Balance to surplus	3,905.95
	$44,751.87

NECROLOGY

CHARLES W. BATCHELOR

Charles W. Batchelor was born in London, England, December 21, 1845. Soon afterwards his parents moved to Manchester, where he received a liberal education and where he served his apprenticeship in several of the largest engineering works of that place. At the age of twenty-two years he came to this country to install some machinery for the Clark Thread Company of Newark, N. J., and almost from the first was for over twenty years intimately associated with the inventor Thomas A. Edison, assisting in the development of the electric pen, the telephone transmitter, the phonograph, the electric railroad and the Edison incandescent lamp and lighting system.

In 1881 he went to Europe to represent the Edison interests at the Paris electrical exhibition of that year, and remained in Paris, for three years where he was the first to introduce the system of electric lighting. He made the original installation at the Paris opera house, and started a number of isolated plants in other parts of Europe; at the same time establishing and managing a large factory at Ivry.

Returning to this country in 1884, he assumed the management of the Edison Machine Works, an organization which in course of time developed into the Edison General Electric Company, and the selection of the site of their large works at Schenectady was made by him. Later this company combined with the Thomson Houston Electric Company and became the General Electric Company.

Of late years he had practically retired from business and devoted much time to travel, though he retained the presidency of the Taylor & Co. iron foundry, a concern in which he had been interested since its establishment.

Mr. Batchelor was a member of the Natural History Museum of New York and the New York Botanical Garden. He was a member for a number of years of the American Geographical Society, the American Institute of Electrical Engineers and the American Electrochemical Society. He entered this Society in 1880.

He died at his residence in this city on January first, 1910.

PERCY A. SANGUINETTI

Percy A. Sanguinetti, one of the early members of the Society, was born in Kingston, Jamaica, B. W. I., June 17, 1844, and died at his home in Mt. Vernon, N. Y., on January 30, 1910.

At the age of 16, he entered service as an apprentice in the locomotive shops of his native town. A few years later he received an appointment to the British Navy Yards at Chatham, England, where he worked through the various departments. During this time he passed a successful examination as teacher of mechanical drawing in the evening mechanical schools at South Kensington, London. In 1867, he was appointed by the Admiralty Board to represent the town of Chatham at the Paris Exposition and to report upon its mechanical features.

His experience in the United States dates from the Centennial Exhibition at Philadelphia in 1876, where he served as assistant to the machinery bureau, designing the system of shafting and the cascade in the pump annex and assisting in the experiments with turbines. At the close of the Exhibition he entered the service of the Franklin Sugar Refinery in Philadelphia, where he remained twelve years, conducting during part of this time a course in mechanical engineering at Franklin Institute. In 1893 he acted as mechanical aid at the World's Columbian Exposition in Chicago and for the following three years occupied the chair of mechanical engineering at the Armour Institute of Technology. In 1895 he came to New York to engage in consulting practice and during the past two years has served in the appraisal bureau of the Public Service Commission.

In 1901, Mr. Sanguinetti secured the coöperation of a score of representative manufacturers of this country in the introduction of American machinery into Jamaica, especially in sugar plantation and power development. His latest work was the remodeling of a sugar refinery near New Orleans, which he completed just two months before his death.

DEDICATION OF MEMORIAL TABLET TO ROBERT HENRY THURSTON

A bronze memorial tablet to Dr. Robert Henry Thurston, first president of The American Society of Mechanical Engineers, was dedicated at the New York monthly meeting, Tuesday evening, February 8, 1910, in the auditorium of the Engineering Societies Building, in the presence of many associates and former students of Dr. Thurston as well as of members of the Society. This bas-relief, which is the work of Herman A. MacNeil, a former student and personal friend of Dr. Thurston, and is a replica of the memorial tablet presented to Sibley College, Cornell University, by alumni and students, was placed in the rooms of the Society through the generosity of members, as an expression of their devotion to Dr. Thurston. The contributions were received by a committee consisting of John Fritz, S. W. Baldwin, Prof. R. C. Carpenter, Walter C. Kerr, E. A. Uehling, Wm. Hewitt and Gus. C. Henning; and the details connected with the acquiring of the tablet, its installation and the arrangement of the dedicatory exercises, were in the hands of Dr. Alex. C. Humphreys, *Chairman*, Chas. Wallace Hunt, Fred J. Miller, Prof. R. C. Carpenter and J. W. Lieb, Jr.

The program of the evening was designed to cover the various phases of Dr. Thurston's brilliant career, treated in each case by a speaker of wide reputation who had known Dr. Thurston intimately during this period of his life. It therefore very appropriately included an address on Dr. Thurston's relationship with the Society, by Prof. John E. Sweet, President of the Society from 1883–1884 and active with Dr. Thurston in its organization; a communication on Dr. Thurston's career as a naval engineer from Rear-Admiral Benjamin Franklin Isherwood, U.S.N., Retired, Honorary Member of the Society, which was read by Prof. F. R. Hutton, Honorary Secretary; an address on Dr. Thurston at the Naval Academy at Annapolis, by Rear-Admiral George W. Melville, U.S.N., Retired, Honorary Member and Past-President, Am.Soc.M.E.; on Dr. Thurston as professor at Stevens Institute of Technology, by Col. E. A. Stevens,

trustee and treasurer of Stevens Institute and son of its founder; on Dr. Thurston's literary and research work, by William Kent, one of the organizers of the Society and a close friend and co-worker with Dr. Thurston; and on Dr. Thurston as director of Sibley College, Cornell University, by Walter C. Kerr, a trustee of Cornell.

After the addresses of the evening, members and guests proceeded to the eleventh floor where the tablet was unveiled and presented by Dr. Humphreys, on behalf of the committee, to the Society, for whom it was accepted by Col. E. D. Meier, Vice-President. Col. Meier cites this as the first bronze statue of an eminent engineer to be erected in the United States in a great building devoted entirely to engineering and said that an excellent choice had been made of Dr. Thurston as a representative of his profession. Dr. Humphreys also presented Herman A. MacNeil, the artist, to the audience, who made the concluding remarks of the evening.

The addresses of the evening follow.

It was a matter of regret that Mrs. Thurston found it impossible to be present at the meeting. A letter was read by the Chairman, expressing her appreciation of the honor rendered to Dr. Thurston. Messages were also received from President Westinghouse, who was prevented by urgent business from attending, and from Chief Engineer Chas. H. Manning, U. S. N., and Lieut-Commander Robert Crawford, U. S. N., associated with Dr. Thurston in the Naval Academy at Annapolis.

The Chairman of the Thurston Memorial Committee, Dr. Alex. C. Humphreys, president of Stevens Institute of Technology, presided over the meeting, and said in his introductory remarks:

REMARKS BY DR. ALEX. C. HUMPHREYS, CHAIRMAN

While recognizing that it is not the function of a presiding officer to forestall the speakers to be introduced, I cannot refrain from saying a few words about my friend and preceptor, Robert H. Thurston. Others will tell you of his widely varied activities, his tremendous capacity for work, which was nevertheless overtaxed, his quickness of brain and speech, his powers of exact determination and expression, his capacity for organization and execution, his eminence as an engineer and educator. I prefer to think of him as the large-hearted, gentle, lovable, helpful man; the man of vision, the optimist.

While a student at Stevens, I was not fortunate enough to have Dr. Thurston's guidance during my junior year, for then, in 1879, he had

not yet recovered from the almost fatal nervous breakdown, which resulted from his strenuous life in many lines of activity. But I came to know him well during my senior year, and had many occasions to be deeply grateful to him for his assistance and encouragement, which I then greatly needed. I never saw him other than cheerfully responsive to a request for help, and I was never allowed to feel that I was intruding when I went to him for counsel. While demanding respect and obedience from those under him, his attitude towards them was characterized by a sympathetic desire to be helpful.

Wm. Kent, one of the speakers of the evening, in his masterly biographical notice of Dr. Thurston in the Sibley College Journal, in writing of the vast amount of work performed at a certain time by Dr. Thurston, says: "And during all this time, I never saw him excited or ruffled over his work." We busy, overcrowded men, know this to be high praise indeed.

I met Thurston too seldom after I graduated from Stevens, but when we did meet, I was made to feel that he was really interested in my career, and that he rejoiced and sympathized with me as circumstances suggested. I like to remember that he came down from Cornell at the time of my inauguration as president of Stevens Institute, and that it was through him that Cornell University and Sibley College conveyed their good wishes to Stevens Institute and to me at that time. Later in that year he quietly passed away to his well-earned rest.

Thurston was a man of vision. Time and again this is shown in his writings, and especially in view of later developments. And this, notwithstanding that his declared results were sometimes afterwards to be amended, as must be the case of those who are courageous enough to act the part of pioneers.

We are, apparently, now only beginning to appreciate in this country the practical and commercial value, to say nothing of higher things, of technical and technological education. And even now, those who do have the appreciation are unable to move and guide those who have the power to provide the means for the necessary improvement in our educational methods. Years ago, Thurston wrote: "Germany has substituted for the now obsolete apprenticeship system, the systematic, scientific methods of preparing her youth for the future of their lives in all departments of instruction and industry."

He was a student of political economy and education and pointed out the evils which would come to us unless certain lines of reform were followed, the evils which are now upon us and have to be met by patience, wisdom, firmness and common sense.

It was said of his father: "Throughout his life, his benevolence, his uniform kindness to employes and to all with whom he came in contact, and his strong attachment to his friends, made him as universally beloved as he was widely known."

The son was strong in faith though he did not carry his religion in his sleeve. He gave voice to his faith in a certain article which he wrote under the title. The Scientific Basis of Belief, which received wide attention. It seems to me that the summation of his creed is found in a verse which he included in this article:

Strong Son of God, immortal love,
Whom we, that have not seen Thy face,
By faith, and faith alone, embrace,
Believing where we cannot prove.

Notwithstanding his great and varied accomplishments, it is as the holder of this faith, and as the worthy son of this worthy father, that I love to think of Robert H. Thurston.

DR. THURSTON'S CONNECTION WITH THE SOCIETY

By John E. Sweet

Honorary Member and Past-President, Am.Soc.M.E.

We meet tonight to do honor to the first president of The American Society of Mechanical Engineers, elected now nearly thirty years ago. I have been asked to tell the simple story of his connection with the Society. It is fitting that we whose fading memories can give only shadowy reviews of past events do the best we can to record the facts as we recall them.

To begin at the beginning we must hark back to the fall of 1879, when the American Machinist was published in a small office at 96 Fulton St., New York. The journal had been in existence but a few years. It had received contributions from a goodly number of contributors engaged in various branches of mechanical industries and from a wide section of the country. But very few of these contributors were known to the publishers, and fewer still to one another, and the notion came to my mind to get as many of them together as we well could, and give the publishers a surprise party; with a faint notion that it might lead to an organization. I conveyed the notion to one of the contributors, and he at once gave it away to the editor, with the suggestion that some sort of a mechanical association be formed. The suggestion took root in the minds of

the publishers, and Mr. Bailey, the editor, came to Syracuse to see me about it; or, in fact, to inveigle me into writing the invitations.

Among those invited were Alexander L. Holley and Prof. Robt. H. Thurston, then in a sanitarium in Dansville, N. Y., both of whom entered heartily into the scheme. Before the meeting, which was held on February 16, 1880, Mr. Bailey and I had an interview with Mr. Holley; each was to draw up some form of program for the meeting, and we were to meet the next day to compare notes. As such things usually turn out, Mr. Holley had drawn up a set of rules which were so complete that we could readily endorse them. At the meeting in the afternoon there were something like thirty present, with letters of endorsement from fifteen or twenty others. Mr. Holley acted as chairman, and I well remember the point he made in his opening address, that it had come to that state of affairs that both civil and mining engineering were largely mechanical. A good deal of time was spent in discussion of the rules, which ended in the adoption of those Mr. Holley had prepared; and time was also wasted in settling on a name, until Mr. Copeland said, "Call it 'The Society of Mechanical Engineers." This seemed to settle it, except that in the shuffle the word "American" got incorporated, to the regret of possibly no one but myself.

Mr. Copeland, Charles T. Porter, Mr. Holley, E. D. Leavitt, Jr., and myself were chosen as a nominating committee. The officers nominated were elected at the meeting held April 7, 1880, at the Stevens Institute, over which Henry R. Worthington presided.

At the time of what is now known as the first annual meeting, held in New York, November 4 and 5, 1880, Professor Thurston had regained his health, and was able to preside and to deliver an able address. Professor Thurston was elected president for the second time, and these two were the critical years in the Society's history. We then held three meetings a year, and while Holley and Worthington lived, they formed with Professor Thurston a three-point support that did not rock; but they both died while Thurston was President, and left him to carry the burden. One incident that occurred during this time I shall always remember. Going out from one of the meetings Mr. Worthington, greatly elated over the way things were moving, said to me, "Professor, the thing is going to go." I doubt if any of us had the idea that the Society would reach a membership of 300, while today it takes another right hand cipher to record our membership.

Professor, later Dr. Thurston, not only while president, but for a

long time later, was more instrumental in helping up the Society than any other man. It is not necessary to enumerate his contributions to the Transactions. He never showed evidence of elation at success or chagrin at defeat. His work enriches every volume of the Transactions, from the first volume down to the time of his death. And every member of the Society needs to open the door of his memory and let the history of its work shine in and enliven his spirit of respect and adoration for the boy, the student and the scholar, the thinker and the worker, the teacher and the guide, the honored member and revered first President of The American Society of Mechanical Engineers, and the man—Dr. Robert Henry Thurston.

DR. THURSTON'S CAREER AS A NAVAL ENGINEER

By Rear-Admiral Benjamin F. Isherwood

Engineer-in-Chief, U.S.N., Retired, Hon. Mem.Am.Soc.M.E.

Professor Thurston, in whose honor these commemoration exercises are held, was in all respects an exceptional person, with endowments not only of a very rare but of a very high order. He was a typical representative of the American engineer of the present day; combining a thorough and extensive practical knowledge of his profession with a scientific culture scarcely found in the exclusively theoretical scientist; and he had, in addition, the ability to make these qualifications available to the world by means of an excellent literary education improved by a carefully discriminating practice as a writer, an orator, a mathematician, and an original investigator in the broad field of his profession. The first-class engineer of the present day must also be a first-class scientist as well as a first-class mechanician, besides possessing a mind well stored with the information collected by others of his profession whose aims and achievements are similar to his own.

With these mental powers was associated, in the case of Professor Thurston, so charming a personality that he not only never had a foe, but all who knew him were his friends. His knowledge and his services were at the command of all who sought them, and were rendered in a manner that made the recipient believe that instead of receiving a favor, he was conferring one. Professor Thurston was the author of several books on engineering subjects, which were classics in their day. He was also a prolific investigator of difficult phenomena in engineering, and his numerous reports have much

enriched its literature and enlightened its obscurities. He wrote with perspicuity, elegance and ease; and he was a ready and fluent orator on all the scientific topics of the day.

His death was a great loss to the world, and particularly to his own profession of engineering, for his exceptionally valuable life was devoted to the improvement of the world in the only way it could, in his opinion, be improved, namely, by the cultivation of physical science. Great intellectual attainment meant with him, great everything else.

Those who knew Professor Thurston best valued him the highest. My personal acquaintance with him was long and intimate, and it was intensified by our professional interest in the same subjects, notwithstanding the great difference of our ages and temperaments; and none who knew him as well as I did will consider this weak portraiture of him as overcolored. His death at Cornell saddened all who knew him well enough to appreciate his gentle qualities, as well as his lofty aspirations. He was most happily constituted; he lived his life in the sunshine of an entirely normal existence, and by dying in the full flush of manhood and in the consciousness of great achievement, he was saved from decline, and enabled to pay to glory the debt he owed to nature.

DR. THURSTON AT THE NAVAL ACADEMY AT ANNAPOLIS

By George W. Melville, Rear-Admiral, U.S.N., Retired

Honorary Member and Past-President, Am.Soc.M.E.

My function is to pay the tribute of the navy to one who was for a time a naval officer and who during his career as such bore himself in a way worthy of its best traditions, and left a record the memory of which is still distinct with those of us who were his contemporaries although it has long since been overshadowed by the greater reputation of his more mature life.

When the engineer came into the navy, he received scant recognition, although we were very fortunate indeed in having as our first representative that grand old man, Charles H. Haswell, who was taken from us so recently. The dominant faction in the navy did not like machinery nor mechanics, and as a result the very early engineers were largely men whose theoretical training did not go beyond the common schools and whose professional training came from hard knocks in the machine shop. This was true in my own

case and in that of the great majority of the older engineers. At the breaking out of the Civil War, however, with the increased demand for engineers and the desire of patriotic men with engineering training to render their best service to the Government, a number of men came into the corps who were college graduates, and Dr. Thurston was one of these. He entered the service in July 1861, very soon after the beginning of hostilities and before any of the great naval battles, and he served at sea continuously until the close of the war, taking part in the Battle of Port Royal and in the Siege of Charleston. While still a second assistant engineer, he was placed in charge of the machinery on the Chippewa and later served on the monitor Dictator, the largest built up to that time.

The historian of the engineer corps of the navy, Past Assistant Engineer (now Captain) Frank M. Bennett has mentioned several instances in which Thurston distinguished himself. One of these was on January 29, 1863, when he was in command of one of the armed boat's crews which captured the blockade runner Princess Royal at Charleston. The next day two armored rebel rams came down upon the Federal fleet and destroyed some of the converted merchantmen which constituted it. Thurston was temporarily chief engineer of the Princess Royal and by extraordinary efforts managed to get the machinery going so that she got out to sea and escaped destruction at the hands of the rebels.

With his fine preliminary training at Brown University and his four years of practical experience in the navy, it was obvious that he was well equipped for duty as an instructor at the Naval Academy in the department of natural and experimental philosophy, to which he was ordered in 1865. During his term of service there, the head of the department died and Thurston was made acting head of the department.

It was during this time that the education of engineers at the Naval Academy began with the class of acting third assistant engineers who entered in 1866, of whom the late Admiral Rae was a member. Thurston undoubtedly gave instruction to all of these young engineers in that department, which we would now call thermo-dynamics, although he was not a member of the department of engineering which looked after the more practical side of their professional training.

A retired engineer officer, who was an instructor at Annapolis in the department of engineering, while Dr. Thurston was in the department of physics, speaks of him as follows: "During about two years

of his term at Annapolis, I saw him almost daily and am therefore able to bear testimony to the excellent work he then did both as an instructor and as the managing head of that very important department of our Naval School. He fully appreciated the importance of physical science to the naval profession generally, and its particular application to naval engineering, and he worked with untiring zeal for its full development as a part of the training of our young officers, often personally designing special apparatus, which were fewer then than now, for demonstrating physical truths and principles. Thurston was eminently fitted for this class of scientific work by taste, education and practical experience as a naval engineer.

At such a time as this, we realize how very interesting it would be if we could know exactly what circumstances lead to the selection of a man for a particular line of work. I have tried hard to find just what led to Dr. Thurston's selection for the chair of mechanical engineering in Stevens Institute, but it occurred so long ago, almost forty years, that the details are no longer available. Indeed it is probable that there never was any record of them and that it was a matter between President Morton and Dr. Thurston himself. Unless a man writes an autobiography, and is as frank about all the occurrences of his life as Herbert Spencer, such an interesting phase as this is apt to be entirely passed over in spite of its great importance. Aware, as those of us who knew him well are, of Thurston's marked ability as a scientific expositor and of his life-long desire for progress and increased efficiency, may we not imagine that, before he was asked to become President of Stevens, President Morton had become acquainted with Dr. Thurston through his articles; and by correspondence or conversation had found that here was a man after his own heart, who could be counted upon to make the new school of technology what he wanted it to be, the best in the country.

There were other departments of colleges and perhaps other schools where mechanical engineering was taught, but Stevens was, I believe, the first institution in our country devoted exclusively to the education of mechanical engineers, and we can now realize even better than when he was called to the Chair, how extremely important was the selection of Dr. Thurston for this work. If he had been content to drift along in accordance with old established methods, or if he had not been a tremendous worker, his great ability would have failed to give to Stevens the foremost standing which it has held from the very start.

Dr. Thurston had, in a degree rarely found among men devoted

to education, a strong touch of the commercial instinct, and it was doubtless this which led him, from the beginning, to direct the work of his students in their experiments along lines of an immediately practical interest to engineers and others. For example, I remember a set of experiments to determine the economy of gas engines at a time when they were just coming into use. This was only one of a great many instances. The hard-headed, practical manufacturers could not fail to realize that a school where the energies were directed in such a practical way must turn out men who would make good in practical life. I need hardly show that this judgment has been verified by recalling the positions now held in offices of the very highest importance in the lines of manufacturing and transportation by many of these graduates.

So great was the reputation made by Dr. Thurston at Stevens, that he was generally looked upon as the greatest teacher of mechanical engineering in the country; and I happen to have information with respect to the circumstances under which he went to Cornell which show that when they were looking for a man of the highest accomplishments to take charge of Sibley College, they at first did not consider Dr. Thurston, for the reason that they did not believe any inducement could take him away from Stevens. When the Trustees of Cornell came to the conclusion that they wanted the best man available, and that they were willing to pay whatever was necessary to secure his services, they eventually opened negotiations with Dr. Thurston, which led to his finally going there.

Of his splendid work at Cornell others will speak, and I need only say that it is a marvelous tribute to his ability and reputation that he should have been able to increase the attendance at Sibley College from about one hundred students to over one thousand.

His educational work was so engrossing that it naturally left him little time for keeping up his association with the Navy although we who remained in the service always felt that in him we had a sincere friend on whom we could depend for such help as was in his power to give whenever the engineers of the Navy needed assistance. Before we finally attained the full recognition of the paramount importance of engineering in the Navy, which, as you know, is now the function of the entire line of the Navy, we had many an up-hill fight, and on several occasions Dr. Thurston materially assisted us by articles in the magazines and by personal appeal. In this connection it is interesting to note that Bennett's History of the Steam Navy, in speaking of an order of the Navy Department in

1870, which was considered very unfair to the engineer corps, mentions that, in consequence of this order, a number of the brightest men in the corps resigned, among them Dr. Thurston. It has been my observation that the participants in an up-hill fight are drawn more closely together than those whose association is always on the winning side. It was doubtless Dr. Thurston's keen recollection of the lack of recognition which he had received while an engineer in the Navy, that made him so willing to help those who were still in the service in their efforts for a proper recognition and consideration of engineering and its exponents.

It has been my desire as a naval engineer and one whose whole life has been spent in the naval service, to voice, in behalf of myself and my colleagues who were and are engineers in the Navy, our admiration for the friend who, during his own short naval career, did so much to add to the reputation of the engineer corps, and by his prominence as an engineer all through his life reflected the highest credit upon naval engineering.

DR. THURSTON AT STEVENS INSTITUTE OF TECHNOLOGY

By Col. E. A. Stevens

Member of the Society, Trustee and Treasurer, Stevens Institute

Thurston's work at Stevens can be divided into two parts: on the one hand his general work as an engineer, including his well known contributions to the literature of engineering and the researches on which they rested, and on the other his share in the development of the work of the Institute and the influence of his personality on his fellow instructors and the undergraduates.

As to the first part I can say but little in the time assigned. The history of mechanical engineering in the United States will always bear witness to his ability, to his untiring energy and to the liberality with which he freely gave to his beloved profession all that his ripe experience and trained observation could give.

Whatever may have been the value of his other work while at Stevens, none of it surpasses, or I may say equals in importance, his share in the development of the system of instruction and the influence of his personality and of his standard of professional ethics on those with whom he was there thrown into contact.

Forty years ago the American mechanical engineer was mainly

the product of the shop and the engine room, with such self-teaching as could be gathered in the leisure hours of a busy life of hard work. Most engineers of that day would admit that draughting and mathematics could be taught in schools, but claimed that such training would produce draughtsmen and mathematicians, not engineers, men who would be of less value in practical work than the lad of the same age who had spent his time in the shop; that the school-bred man would need several years of hard work to knock the school-taught nonsense out of his head, always granting that he had not been irretrievably ruined by his scholastic training.

Such was the general, even if not the unanimous mind of the profession when Henry Morton gathered around himself six men, who with him were to form the faculty of the first American school wholly devoted to the teaching of mechanical engineering. Scientist and scholar as he was, Morton appreciated the gravity and importance of the task set him and selected his fellow members of the faculty with a care and judgment amply justified in the result. Of these men, eminent as they were, Thurston was the one on whom devolved the practical teaching of engineering. The others must have aided, and unquestionably did aid, in giving the training as a whole a practical direction, but it was to Thurston more than to any one other of Morton's first faculty that the prominence of the practical curriculum at Stevens must have been due, and on him therefore it is but fair to bestow a generous share of the acknowledgment due these men. It would be as invidious as it would be useless to apportion to each the share due to his individual efforts.

While Thurston's personality impressed itself on all who met him, whether at Stevens or elsewhere, the lasting result of this impression on the men who there studied under and with him forms a part of the history of Stevens. The material that came to the "Old Stone Mill" was much the same in the early days as since. The early graduates at once took a standing in American engineering work that soon settled once and for all any debate as to the value of a technical training. They carried also with them into the world what was as necessary for the progress of engineering as technical skill or practical knowledge. They had imbibed together with their calculus and thermodynamics that moral and ethical view of their profession without which an engineer's skill and learning is of little value to his country, a thing not absorbed from text books or taught by platitudes, however often reiterated from the lecture platform.

Boys and young men quick to detect cant are equally quick to

recognize and value square-dealing and to love and follow and model themselves after the straightforward man. Of all of that first faculty there was no one to whom the undergraduates could and did more confidently look for a square deal than to Thurston. That straight clear gaze, right into your eye, gave at once a confidence in the man and in his methods in and in a feeling of sympathy that experience did not belie.

Single examples prove few cases and a life such as Thurston's is not to be judged by citing examples and incidents. The true measure of his great work and usefulness is to be fixed by the standard set by the great Master, "by their fruits ye shall know them." By no other standard would Thurston have asked to be judged and the fruits of his work at Stevens are proven not by the accomplishment of specially gifted men who studied under him but by the general standing of the Stevens men of this day.

DR. THURSTON IN LITERATURE AND IN RESEARCH

By Wm. Kent, Mem.Am.Soc.M. E.

My acquaintance with Dr. Thurston began near the end of the year 1874, when I called upon him to make arrangements for entering the junior class in the Stevens Institute of Technology. He was then thirty-five years of age. He was at this time professor of mechanical engineering, meeting his classes two hours a day for, I think, five days in the week; he was editing the four volumes of reports of the United States Commission to the Vienna Exhibition of 1873, one of the volumes being written by himself; he had shortly before written a report of the United States Commission for investigating the causes of steam-boiler explosions; he was planning the researches to be made by the United States Board to test iron, steel and other metals, of which he was secretary and the most active member. Besides all this he was writing papers for the American Society of Civil Engineers and for the Journal of the Franklin Institute, concerning the results of his researches. In 1871 he had conducted a series of boiler tests on several different makes of water-tube boilers at the American Institute fair in New York. In 1873 he had organized a mechanical engineering laboratory for the purpose of making engineering researches, the first of the kind to be established in the United States. At about the same time he invented his well-known autographic testing machine for testing materials by torsion, and

later he invented the machine for testing lubricants, in which some of the principles of the torsion machine were embodied.

In June 1875, Dr. Thurston called me into his office and told me he wanted me to undertake a research into the strength and other properties of the alloys of copper. I said to him, "I don't know anything about alloys." "That is a good qualification," said he, "you won't have anything to unlearn." He told me how to make a research into the literature of the subject, and how to find indexes to such literature. He had me write him a report of all I could find that was then known about the alloys of copper and tin and copper and zinc, and after studying it he planned a series of tests to be made in the laboratory, which took eighteen months to complete During all this time I had to report to him almost every day, and I had a desk in his office. Then began an intimate friendship which lasted until the day of his death. During these two years of companionship I was ever more and more impressed with Dr. Thurston's genius and with the breadth of his intellectual power. Not only was he a tireless worker, driving the pen or pounding the typewriter hour after hour, but his brain always seemed to be working as steadily and as rapidly as his pen. Whenever he was asked a difficult question the answer seemed to come instantly from his well-stored mind, and the answer was right. Such a combination of industry, rapid and clear brain-action, and broad intellectual grasp of a great variety of subjects, engineering and other, I have never known in any other man.

Such intense mental activity as Dr. Thurston exhibited in these years led to its natural result, nervous exhaustion. There was a time in 1876 when he visited the Institute only for a few minutes each day, and five minutes conversation on any technical question would almost prostrate him. During this time he was worried by the fear that Congress would not continue the appropriation for the work of the United States Test Board, and he undertook to write a letter on the subject to one of the senators, but it took him a week or more to write the letter working on it five minutes a day. He gave me a copy of it to take to one of the members of the board in New York City, and that member said to me that it was by far the best presentation of the subject that had ever been made. Such was the quality of his work when he was on the verge of physical collapse.

Here is another example of the kind of work he could do during the same period. He had been planning a series of tests of the triple alloys of copper, tin and zinc, and one day on one of his brief

visits to the institute he said to me: "Here is something I want to show you. Here is an equilateral triangle. It is one of the properties of this triangle that if from any point within it perpendiculars are drawn to each of the sides the sum of these perpendiculars is equal to the altitude. Now let us mark one apex 100 copper, another 100 tin, and the third 100 zinc, and the opposite sides zero copper, tin and zinc. Then any point in the triangle represents one alloy, and all the possible points represent all the possible alloys of the three metals. Now divide each altitude into ten parts, and through the points of division draw lines parallel to the three sides. The crossing points of these lines represent all the alloys whose constituents are even multiples of ten per cent. We will make these alloys and determine their tensile strength, and we will cut a lot of straight wires to lengths corresponding to the strength; then we will set these wires vertically on a board which has the triangle drawn upon it, in holes drilled at the points representing the alloys. We will then fill in this forest of wires with plaster of paris, smoothing it off so as just to leave the tops of the wires visible. We will thus have a topography which shows the complete law of the relation of the tensile strength of the triple alloys to their composition." I well remember my amazement when he had completed the description, that a man with such a worn-out brain should be capable of such a brilliant piece of intellectual work and invention. The investigation of the triple alloys was carried out exactly as he had planned it, and the results were published in the Reports of the United States Test Board, and in Dr. Thurston's book on Alloys.

In 1873 Dr. Thurston discovered the phenomenon of the elevation of the elastic limit of iron and steel. It was also discovered independently in the same year by Commander L. A. Beardslee, U.S.N. In years following he tried to find other metals or alloys that exhibited the same peculiar action after being strained beyond their elastic limit, but never found one. In 1874 he investigated the burning of tan bark for fuel in specially constructed boiler furnaces, and in 1875 and 1876 he made a number of tests of steam boilers. For some years after 1876 he carried on investigations of lubricants, the results of which are in his book on Friction and Lost Work. In later years his researches were not numerous or important, for the reason that his time was fully occupied with other work. It is a matter for lasting regret that the work of the United States Iron and Steel Test Board was discontinued almost before it was fairly started, and before the Watertown testing machine, which was built for its use, was finished.

Dr. Thurston was an omniverous reader, and a tremendously active writer. Prior to 1880 most of his technical writings were contributed to the American Society of Civil Engineers and to the Journal of the Franklin Institute. After that date his engineering papers were mostly given to The American Society of Mechanical Engineers.

Dr. Thurston's literary work was not confined to engineering matters. In 1873 he contributed to the Scientific American a series of seventeen articles on his observations in Europe, which included not only what he had seen at the Vienna Exhibition, and in the several iron works that he visited, but also his reflections on social conditions in the manufacturing centers. Here is a quotation from his remarks on the inferiority of workmanship which then characterized many European productions:

> A liberalization of patent codes, and the gradual training of the workmen of Europe to a knowledge of the importance of good workmanship, and of the methods of securing it, will at a time which we hope is not far distant, do much toward the improvement of the condition of the people. We draw some of our best material from amongst them, and it seems sufficiently evident that not upon nature but upon man's own imperfect political systems lies the responsibility of the unsatisfactory condition of manufactures in Europe.

Dr. Thurston's first important book after his report of the Vienna Exhibition was his History of the Growth of the Steam Engine, published by Appleton in 1878. It is written in his best style, and to those who are at all interested in the subject it is as readable as a novel. It illustrates his painstaking care to be sure of his facts, his skill in arranging them in logical order, and his good judgment in drawing conclusions. In 1877 he brought out a little book on Steam Boiler Explosions in Theory and Practice.

In 1879 he had his second and last nervous breakdown, more serious than the first, so that he was compelled to spend more than a whole year in a sanitarium, doing no work of any kind. He returned to work in 1880, and then followed twelve years of most intense literary activity, during which he brought out an average of a book every year, some of them large octavos of 1000 pages. Here is a list of the books whose first editions appeared in the years 1882 to 1894 inclusive:

- The Materials of Engineering. 3 vol. I, Non-metallic materials; II, Iron and Steel; III, Brasses, Bronzes and other Alloys.
- A Text Book of Materials of Construction.
- Treatise on Friction and Lost Work in Machinery and Millwork.

Manual of Steam Boilers, their Design, Construction and Operation.

Handbook of Engine and Boiler Trials, the Indicator and the Prony Brake.

Translation of Sadi Carnot's "Reflections on the Motive Power of Heat and on Machines fitted to Develop that Power."

Life of Robert Fulton.

Manual of the Steam Engine. 2 vol. I, History, Structure and Theory; II, Design, Construction and Operation.

Stationary Steam Engines, Simple and Compound.

The Animal as a Machine and Prime Motor, and the Laws of Energetics.

Many of these books ran through several editions; the second volume of Materials of Engineering, Iron and Steel, is now in its ninth and the Treatise on Friction and Lost Work, the Manual of Steam Boilers, and Stationary Steam Engines, are each in their seventh edition. The work of revising these books to keep them up to date was no small labor, and several of them have as many as four copyright dates. The Manual of the Steam Engine, and the Handbook of Engine and Boiler Trials, have been translated into French.

Most of these books are severely technical and of interest only to engineers and engineering students; but two of them , the translation of Carnot's little book and The Animal as a Machine, appeal also to those interested in advanced physics. He translated Carnot not because he thought the book would sell, but as he says in his preface, "as a matter of limited but most intense scientific interest," and he compliments the publishers for their undertaking to print the book without any prospect of financial return. Yet in seven years a second edition was printed. Dr. Thurston's appreciation of Carnot in the introduction is a good example of his literary style when writing on non-technical subjects.

Nicholas-Leonard-Sadi-Carnot was perhaps the greatest genius in the department of physical science that this century has produced. By this I mean that he possessed in the highest degree that combination of the imaginative faculty with intellectual acuteness, great logical power and capacity for learning, classifying and organizing in their proper relations all the facts, phenomena and laws of natural science, which distinguishes the real genius from other men and even from simply talented men. Only now and then in the centuries does such a man come into view. Euclid was such in mathematics, Newton was such in mechanics, Bacon and Comte were such in logic and philosophy, Lavoisier and Davy were such in chemistry, and Fourier, Thomson, Maxwell,

and Clausius were such in mathematical physics. Among engineers we have the examples of Watt as inventor and philosopher, and Rankine as his mathematical complement, developing the theory of that art of which Watt illustrated the practical side.

But Carnot exhibited that most marked characteristic of real genius, the power of applying such qualities as I have just enumerated to great purposes and with great result while still a youth. Genius is not dependent, as is talent, upon the ripening and the growth of years for its prescience; it is ready at the earliest maturity, and sometimes earlier, to exhibit its marvelous works; as for example note Hamilton, the mathematician, and Mill, the logician, the one becoming master of a dozen languages when hardly more than as many years of age, reading Newton's Principia at sixteen, and conceiving that wonderful system, quaternions, at eighteen; the other competent to begin the study of Greek at three, learning Latin at seven, and reading Plato before he was eight. Carnot had done his grandest work of the century in his province of thought and had passed into the Unseen at 36; his one little volume, which has made him immortal, was written when he was but 23 or 24.

A fine example of Dr. Thurston's grasp of a subject of scientific thought beyond the domain of engineering, and even beyond the present borderland of physics, is seen in the following brief extract from The Animal as a Machine:

The living body is a machine in which the law of Carnot, which asserts the necessity of waste in all thermodynamic processes and in every heat engine, and which shows that waste to be the greater as the range of temperature worked through by the machine is the more restricted, is evaded; it produces electricity without intermediate conversions and losses; it obtains heat without high temperature combustion; and in some cases light without any sensible heat. In other words, in the vital system of man and of the lower animals, nature shows us the practicability of converting any one form of energy into any other, without those losses and unavoidable wastes characteristic of the methods, the invention of which has been the pride and the boast of man. Every living creature, man and worm alike, shows him that his task is but half accomplished; that his grandest inventions are but crude and remote imitations; that his best work is wasteful and awkward. Every animate creature is a machine of enormously higher efficiency as a dynamic engine than his most elaborate constructions. Every gymnotus living in the mud in tropical stream puts to shame man's best effort in the production of electricity; and the minute insect that flashes across his lawn on a summer evening, or the worm that lights his path in the garden, exhibits a system of illumination incomparably superior to his most perfect electric lights . . . Here is Nature's challenge to man. Man wastes one-fourth of all his fuel as utilized in his steam boiler, and often 90 per cent as used in his fireplace; nature in the animal system utilizes substantially all.

Dr. Thurston was an occasional contributor to such journals as the Popular Science Monthly, the Forum, Science, and the North American Review. Sometimes he went outside of the field of the

physical sciences and wrote on sociological and economic subjects, such as the tariff. Once he wrote for the North American Review a statement of his religious convictions.

He frequently wrote papers and delivered addresses on educational subjects, and in these he was naturally at his best. For nearly forty years he was an educator and an educational leader. He was versed in the theories of Froebel, Milton and Comenius; and of Spencer, John Scott Russell and other modern writers. His paper on Technical Education in the United States; its Social, Industrial and Economic Relations to our Progress, read at the International Engineering Congress at Chicago in 1893, is one of his masterpieces. It is a calm, scholarlike review of the conditions of the past, and a hopeful view of the future. He propounded no new theories, he originated no new fads, but he was in line with the best thinkers of his time, and thoroughly in sympathy with the modern trend toward industrial or trade education for the great mass of the people.

DR. THURSTON AT SIBLEY COLLEGE, CORNELL UNIVERSITY

By Walter C. Kerr, Mem, Am.Soc.M.E., Trustee Cornell University

What a man is, makes less difference to the world than what his life teaches; the man departs, but his teaching remains. It would be impossible for me to relate here the full importance of the eighteen years that Dr. Thurston devoted to Cornell University. Prior to 1885 Cornell was developing a department of mechanic arts in a small way, recognizing the necessity and opportunities of mechanical engineering. With a profitable sale of the university's timber lands the trustees felt warranted in taking forward steps, chief among which was the founding of a new department, and to this department of mechanical engineering Dr. Thurston was called as the first director. No choice was ever more fortunate. I will not undertake to recount all that followed in physical development from his administration, except to say that the number of students increased from one hundred to eleven hundred, buildings grew, facilities grew, everything that his hand touched grew, and all the growth was healthy. Professor Thurston was especially an organizer, and of the very best kind. This was because he knew what to organize. His methods were direct and practical, he knew men, he understood human nature; and all resistance was to him merely a retardation, not a stopping, and consequently he gained whatever he set out to do.

By temperament, education and experience he was peculiarly fitted to direct socially and intellectually an important department in a complex institution; by his touch with all the forces of life he was an important factor in any community in which he lived, and this gave him a profound and wide influence for good through a much larger circle than that of engineering. He convinced men, by persuading them to want what he wanted, and the result was that he usually gained his end with the minimum of argument. His ever-present cheerfulness was an inspiration, and his patience was an example. There is no subtle mystery about why he was so loved and respected at Cornell, nor why he accomplished so much. His ways were ways of peace, and his achievements were a series of creative victories. He was a strong man, so strong that we honor his memory tonight. He has gone, but the influence of his life lives.

TEST OF A 15,000-KW. STEAM-ENGINE-TURBINE UNIT

H. G. Stott, New York
Member of the Society

R. J. S. Pigott,[1] New York
Non-Member

During the year 1908 it became apparent that owing to the cost increasing traffic in the New York subway, it would be necessary to have additional power available for the winter of 1909–1910.

2 The power plant of the Interborough Rapid Transit Company, which supplies the subway, is located on the block bounded by 58th and 59th Streets, and by 11th and 12th Avenues, adjacent to the North River; it contains nine 7500-kw. (maximum rating) engine units, besides three 1250-kw. 60-cycle turbine units which are used exclusively for lighting and signal purposes.

3 The 7500-kw. units consist of Manhattan-type compound Corliss engines, having two 42-in. horizontal high-pressure cylinders and two 86-in. vertical low-pressure cylinders. Each horizontal high-pressure cylinder and vertical low-pressure cylinder has its connecting rod attached to the same crank, so that the unit becomes a four-cylinder 60-in. stroke compound engine with an overhanging crank on each side of a 7500-kw. maximum rating 11,000-volt, three-phase, 25-cycle generator. The generator revolving field is built up of riveted steel plates of sufficient weight to act as a flywheel for the two engines connected to it. This arrangement gives a very compact two-bearing unit. The valve gear on the high-pressure cylinders is of the poppet type, and on the low-pressure of the Corliss double-ported type.

4 The condensing apparatus consists of barometric condensers,

[1]Interborough Rapid Transit Company.

The American Society of Mechanical Engineers, 29 W. 39th St., N. Y.
All papers are subject to revision.

arranged so as to be directly attached to the low-pressure exhaust nozzles, with the usual compound displacement circulating pump and simple dry-vacuum pump.

5 These engine and generator units are in general probably the most satisfactory large units ever built, as five years' experience with them has proved; their normal economic rating is 5000 kw., but they operate equally well (water rate excepted) on 8000 kw. continuously.

6 In considering the problem of how to get an additional supply of power, every available source was considered, but by a process of elimination only two distinct plans were left in the field.

7 The electric transmission of power from a hydraulic plant was first considered, but owing to the high cost of a double transmission line from the nearest available water power, and the impossibility of getting reliable service (that is, service having a maximum total interruption of not more than ten minutes per annum) from such a line, further consideration of this plan was abandoned.

8 The gas engine, while offering the highest thermo-dynamic efficiency at the same time required an investment of at least 35 per cent more than an ordinary steam-turbine plant with a probable maintenance and operation account of from four to ten times that of the steam turbine.

9 The reciprocating-engine unit of the same type as those already installed, was rejected in spite of its most satisfactory performance, on account of the high first cost and small range of economical operation. Reference to Fig. 1, Series A will show that the economic limits of operation are between 3300 kw. and 6300 kw.; beyond these limits the water rate rises so rapidly as to make operation undesirable under this condition, except for a short period during peak loads.

10 The choice was thus narrowed down to either the high-pressure steam turbine or the low-pressure steam turbine. There was sufficient space in the present building to accommodate three 7500-kw. units of the high-pressure type, or a low-pressure unit of the same size on each of the nine engines, so that the questions of real estate and building were eliminated from the problem.

11 The first cost of a low-pressure turbine unit is slightly lower than that of a high-pressure unit, due to the omission of the high pressure stages and the hydraulic governing apparatus, but the cost of the condensing apparatus would be the same in both cases. The foundations and the steam piping in both cases would not differ greatly. The economic results, so far as the first cost is concerned, would then be approximately the same, if we consider the general

case only; but in this particular instance the installation of high-pressure turbines would have meant a much greater investment for foundations, flooring, switchboard apparatus, steam piping and water tunnels, amounting to an addition of not less than twenty-five per cent to the first cost.

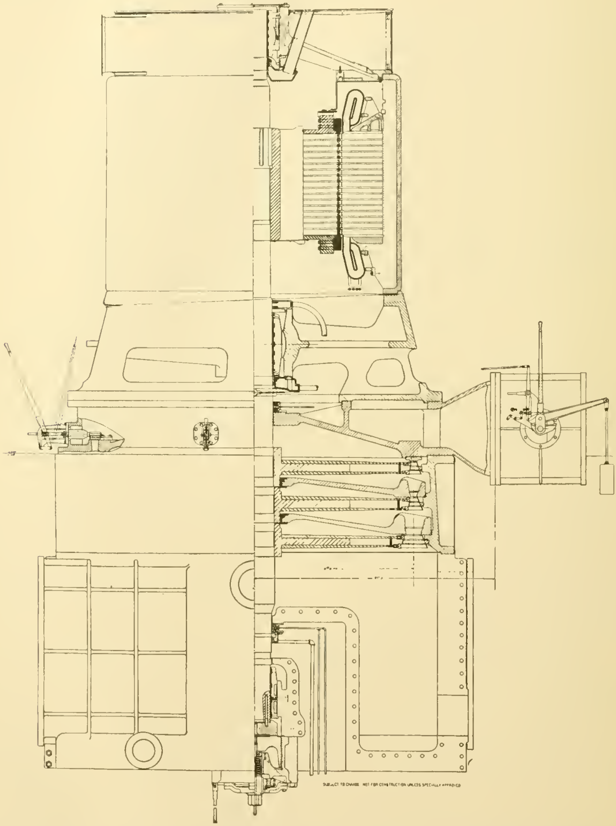
12 The general case of displacing reciprocating engines and installing steam-turbine units in their place was also considered. The best type of high-pressure turbine plant has a thermal efficiency approximately 10 per cent better than the best reciprocating-engine plant, but the items of labor for operation and for maintenance, together with the saving of about 85 per cent of the water for boiler-feed purposes and the 10 per cent of coal, reduce the relative operating and maintenance charges for the steam-turbine plant to 80 per cent, as compared to 100 per cent for the reciprocating-engine plant.

13 Assuming that the reciprocating engine plant is a first-class one and has been well maintained, about 20 per cent of its original cost (for engines, generators and condensers) may be realized on the old plant and so credited to the cost of the high-pressure turbine plant. But on the other hand, if the high-pressure turbine installation is to receive credit for the second-hand value of the engines, it must also have a debit charge for 100 per cent of the original reciprocating-engine plant which it displaced. The relative investments, therefore, upon this basis would be approximately equal for the high-pressure or the low-pressure turbine; but 80 per cent of the cost of the original engine plant would have to be charged against the high-pressure turbine plant, as against an actual increase in value (to the owner) of the engine by reason of its improved thermal efficiency, due to the addition of the low-pressure turbine.

14 The preliminary calculations, based upon the manufacturers' guarantees for the low-pressure and high-pressure turbines, showed that the combined engine-turbine unit would give at least 8 per cent better efficiency than the high-pressure turbine unit, so that it was finally decided to place an order for one 7500-kw. (maximum rating) unit, as by this means we would not only get an increase of 100 per cent in capacity, but at the same time give the engines a new lease of life by bringing them up to a thermal efficiency higher than that attained by any other type of steam plant.

15 The turbine installed is of the vertical three-stage impulse type having six fixed nozzles and six which can be operated by hand, so as to control the back pressure on the engine, or the division of load between engine and turbine. An emergency overspeed governor,

which trips a 40-in. butterfly valve on the steam pipe connecting the separator and the turbine and at the same time the 8-in. vacuum



ELEVATION AND PART SECTION OF LOW-PRESSURE TURBINE UNIT

breaker on the condenser, is the only form of governor used. The footstep bearing, carrying the weight of the turbine and generator rotors, is of the usual design supplied with oil under a pressure of

600 lb. per sq. in. with the usual double system of supply and accumulator to regulate the pressure and speed of the oil pumps.

16 The condenser contains approximately 25,000 sq. ft. of cooling surface arranged in the double two-pass system of water circulation with a 30-in. centrifugal circulating pump having a maximum capacity of 30,000 gal. per hr. The dry vacuum pump is of the single-stage type, 12-in. and 29-in. by 24-in., fitted with Corliss valves on the air cylinder. The whole condensing plant is capable of maintaining a vacuum within 1.1 in of the barometer when condensing 150,000 lb. of steam per hr. when supplied with circulating water at 70 deg. fahr.

17 The electric generator is of the three-phase induction type, star-wound for 11,000 volts, 25 cycles and a speed of 750 r.p.m. The rotor is of the squirrel-cage type with bar winding connecting into common bus-bar straps at each end. This type of generator was chosen as being specially suited to the conditions obtaining in the plant.

18 With nine units operating in multiple, each one capable of giving out 15,000 kw. for a short tine, operating in multiple with another plant of the same size, it is evident that it is quite possible to concentrate 270,000 kw. on a short circuit. If we proceed to add to this, synchronous turbine units of 7500-kw. capacity, which, owing to their inherently better regulation and enormous stored energy, are capable of giving out at least six times their maximum rated capacity, the situation might soon become dangerous to operate, as it would be impossible to design switching apparatus which could successfully handle this amount of energy. The induction generator, on the other hand, is entirely dependent upon the synchronous apparatus for its excitation, and in case of a short circuit on the bus-bars would automatically lose its excitation by the fall in potential on the synchronous apparatus.

19 The absence of fields leads to the simplest possible switching apparatus, as the induction generator leads are tied in solidly through knife switches, which are never opened, to the main generator leads. The switchboard operator has no control whatever over the induction generator, and only knows it is present by the increased output on the engine generator instruments.

20 The method of starting is simplicity itself—the exciting current is put on the engine generator *before* starting the engine, and then the engine is started, brought up to speed and synchronized in exactly the same way as before. While starting in this way, the induction

generator acts as a motor until sufficient steam passes through the engine to carry the turbine above synchronism, when it immediately becomes a generator and picks up the load. Three of these 7500-kw. low-pressure turbine units have been installed and tests run on Nos. 1 and 2. No. 3, having been just started, has not yet been tested.

21 Instead of inserting in this paper the enormous accumulation of data incident to these tests, we have divided the paper into two parts in the hope that it would thus be more accessible for reference, the first part giving the reasons for adopting this particular type of apparatus, with a brief description of the plant and a summary of the results obtained, and the second part containing all the principal data acquired during the tests, with sufficient explanation to make their meaning clear without reference to the text.

22 The tables and curve sheets are as follows:

Series A: Engine tests made in connection with acceptance tests, and also later to determine best conditions for operation.

Series B: Calculations and data furnished by turbine manufacturer to determine probable results when combined with engine data obtained in Series A.

Series C: Tests on No. 1 combined unit. This unit was hurriedly put into commission in order to obtain results to determine future developments. To get the piping done, old riveted steel pipe was used which was very leaky under vacuum. Results are valuable however as showing the effect of vacuum on performance as compared to Series E and F. Quality of steam entering turbine also poor.

Series D: Tests of No. 2 unit, with poor vacuum and poor quality of steam entering turbine.

Series E and F: Tests on No. 2 combined unit; conditions of vacuum and quality of steam entering turbine nearly standard, so that corrections are small.

23 In all results, except where specially noted, moisture corrections are simple corrections, i. e., for each per cent of moisture only one per cent correction has been made. Vacuum corrections for the combined unit are 1 lb. for each inch variation from 28.5 in. when referred to 29.92 in. barometer.

24 The net results obtained by the installation of low-pressure turbine units may be summarized as follows:

a An increase of 100 per cent in maximum capacity of plant.

b An increase of 146 per cent in economic capacity of plant.

c A saving of approximately 85 per cent of the condensed steam for return to the boilers.

d An average improvement in economy of 13 per cent over the best high-pressure turbine results.

e An average improvement in economy of 25 per cent (between the limits of 7000 kw. and 15,000 kw.) over the results obtained by the engine units alone.

f An average unit thermal efficiency between the limits of 6500 kw. and 15,500 kw. of 20.6 per cent.

NUMBER OF TEST	ENG. LOAD	STEAM PR. Gauge	STM TEMP.	STM SUPER-HEAT	RECEIVER PR Gauge (from Temp)	VACUUM Std 29.92" Bar.	QUALITY STM	WATER PER HR	DRY STM P. HR.	REC. DRAIN P HR	STM. TO AUX'L	INJECT WATER TEMP.	DISCH. WATER TEMP.	I.H.P. H.P.	I.H.P. L.P.	I.H.P. TOTAL	DRY STM p.K.W.H	DRY STM. per I.H.P.H.
	K.W.	Lbs.G.	°F	°F	Lbs.G.	"Hg.	%	Lbs.	Lbs.	Lbs.	Lbs.	°F.	°F.	HP	HP	H.P.	Lbs.	Lbs
25	3100	180.1	388.3	9.7	9.13	28.81	100.55	56040	56349	2989	1517	36.8	55.7	2173	2306	4479	18.18	12.58
22	4008	176.7	383.9	5.7	16.87	27.99	100.32	68190	68407	4882	1866	38.4	58.3	2699	2815	5514	17.07	12.42
24	4977	174.4	387.8	10.6	21.7	28.00	100.58	85369	85865	5273	2949	36.8	65.3	3264	4076	7341	17.25	11.70
21	5984	173.9	387.5	10.5	25.9	28.00	100.60	103896	104519	6031	1699	37.73	69.5	3717	4714	8431	17.47	12.40
23	6772	173.3	385.5	8.7	30.0	27.71	100.50	124702	125326	6060	2091	37.7	70.4	4346	5732	10078	18.51	12.37
27	4992	173.9	387.3	10.5	10.44	28.11	100.60	89525	90062	5367	1826	37.76	72.66	3770	5184	6954	18.04	12.95
26	4970	173.2	386.1	9.4	15.21	28.00	100.53	86267	86724	5518	1728	35.9	61.1	3443	3452	6895	17.45	12.58
29	4976	174.9	386.9	9.4	20.41	28.00	100.53	85557	86010	5294	3034	38.1	75.0	3124	3722	6846	17.29	12.59
28	4970	174.3	388.8	11.7	25.35	28.02	100.66	85933	86501	4890	663	36.7	72.6	2982	4127	7109	17.42	12.17
31	3988	177.7	387.5	8.9	32.62	—	100.51	109317	109874	5948				2625	2372	4997	27.55	21.99
32	4980	176.2	386.7	8.7	36.93	—	100.50	128056	128695	6352				2835	3333	6168	25.84	20.88
30	4961	148.2	372.0	7.0	21.06	28.04	100.40	88041	88394	5082	1284	37.46	72.4	3068	4019	7087	17.82	12.48

TABLE 1 SERIES A, ENGINE TESTS

NUMBER OF TEST	ENG. LOAD KW.	B.T.U. ADDED PER POUND WATER	B.T.U REJ. PER POUND WATER	EFF. RANKINE %	EFF. THERMAL %	$\frac{EFF_T}{EFF_R}$ %	B.T.U. DRAINS %	B.T.U. CONS'R & RAD'N. LOSS %	B.T.U. MECH. ELEC. LOSS %	REMARKS
25	3100	1205	840	30.3	15.7	51.7	0.9	71.4	12.0	
22	4008	1202	865	28.0	16.7	59.6	1.3	70.0	Do.	
24	4977	1204	866	28.1	16.5	58.1	1.2	70.3	Do.	
21	5984	1204	866	27.1	16.3	58.2	1.1	70.6	Do.	
23	6772	1203	875	28.3	15.4	56.4	1.0	71.6	Do.	
27	4992	1205	865	28.2	15.8	56.0	1.0	71.2	Do.	
26	4970	1204	866	28.1	16.3	58.1	1.2	70.5	Do.	
29	4976	1205	866	28.1	16.4	58.6	1.2	70.4	Do.	
28	4970	1206	866	28.2	16.4	58.1	1.1	70.5	Do.	
31	3988	1205	1017	15.6	10.3	66.2	1.1	76.6	Do.	Non-condensing
32	4980	1204	1017	15.5	11.0	71.1	1.0	76.0	Do.	Non-condensing
30	4961	1200	875	27.1	16.0	59.7	1.1	70.9	Do.	

TABLE 2 SERIES A

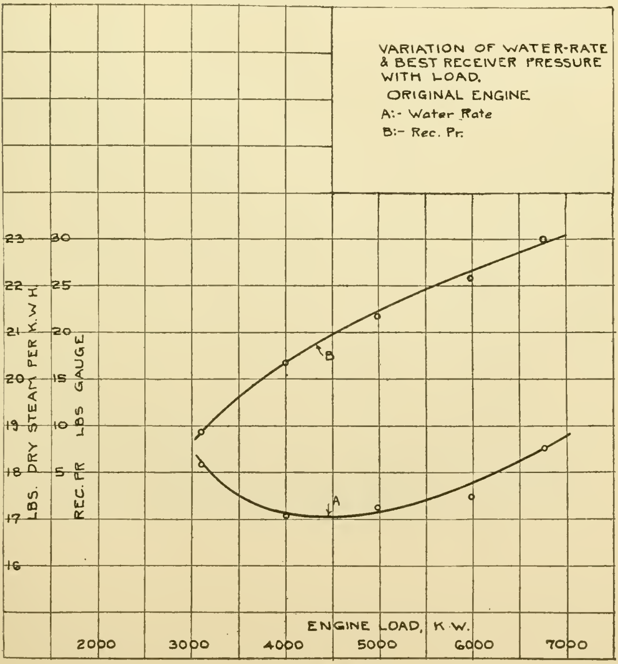


FIG. 1 SERIES A

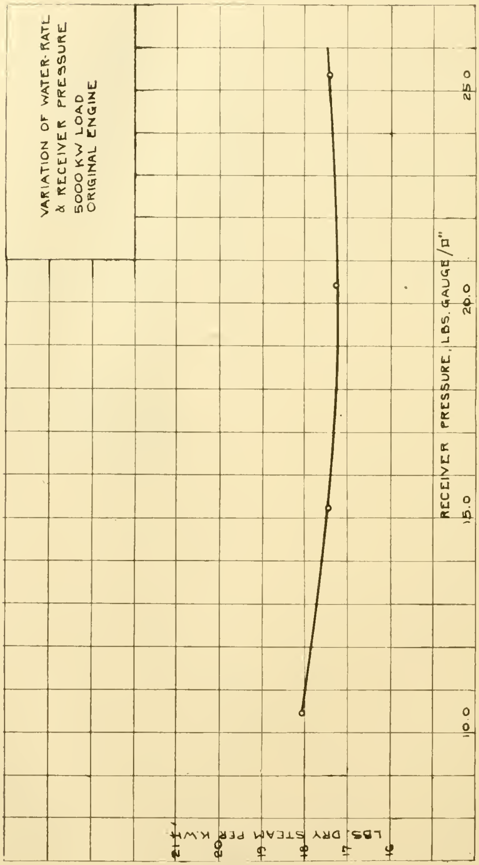


Fig. 2 Series A

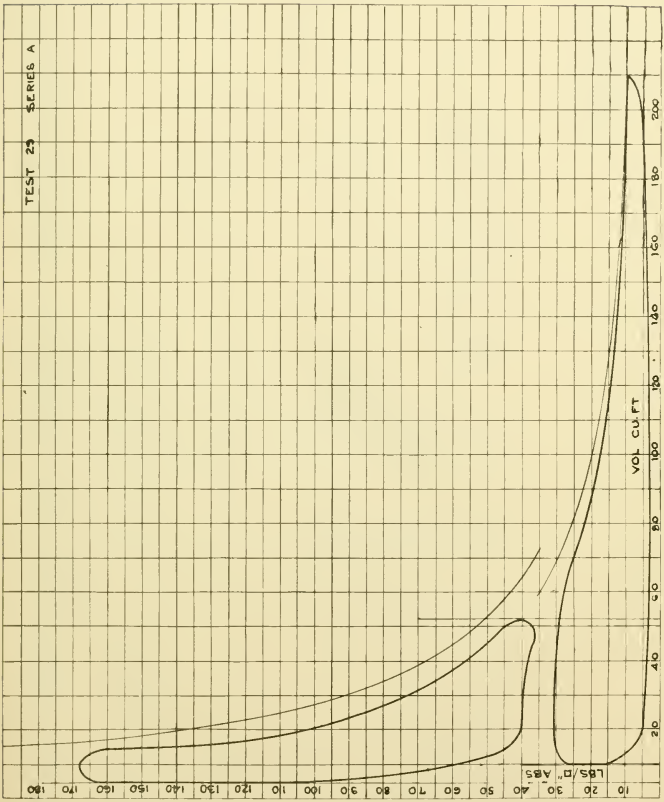


Fig. 3 Series A, Test 29

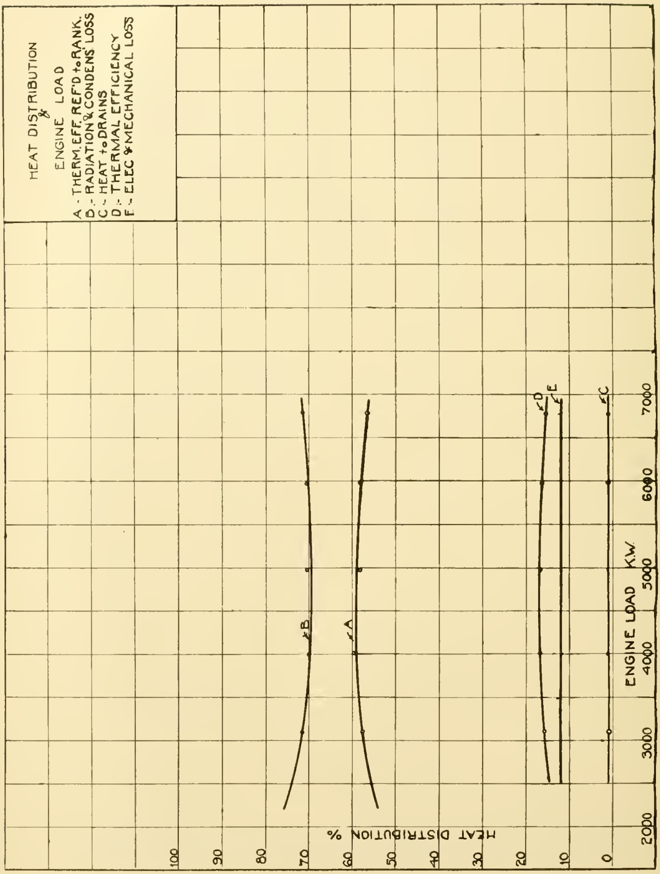


Fig. 3a Series A

NO TEST	LOAD	I.H.P	RATIO HP/LP I.H.P	P_a	P_c	V_a	V_c	W_a	W_c	STM. PER STROKE H.P. CARD	r	y	INDIC. WATER RATE per I.H.P	ACTUAL WATER RATE per I.H.P	ACTUAL WATER RATE per K.W.H.	RECEIVER PRESS.	EXHAUST PRESS.	STM. PRESS.	TOTAL WATER
	KW	IHP		Lbs/□" Abs.	Lbs/□" Abs.	Cu. Ft.	Cu. Ft.	Lbs/Cu.Ft	Lbs/Cu.Ft	Lbs			Lbs/Hr	Lbs/Hr	Lbs/Hr	Lbs/□" Abs	Lbs/□" Abs.	Lbs/□" Abs.	Lbs/Hr
25	3100	4479	.943	137.32	66 12	10.78	7.56	.3058	.1544	2.131	4.80	.469	8.57	12.59	18 18	19 8	.9	191.5	56349
22	4008	5515	.959	143.0	65.3	13 77	9 31	.3176	.1526	2.951	3.41	.298	9.64	12.41	17.07	31.6	1.0	192 8	68407
29	4976	6846	.840	142.4	73.8	16.64	9 30	.3163	.1709	3.670	3 11	.302	9.65	12.56	17.29	36 4	1.0	190.9	86010
24	4977	7341	.801	141 8	75.7	17.13	9.30	.3151	.1751	3.769	3.32	.265	9.24	11.69	17.25	35.1	.9	191.0	85865
21	5984	8431	.789	141 8	74.1	21 48	9.29	.3142	.1716	5.154	2.42	.128	11 00	12.40	17 47	40.6	.9	191.0	104519
23	6772	10078	.759	140.6	89.0	25.40	9.29	.3126	.2037	6 080	2.04	.154	10.86	12.44	18.51	44.7	1.0	190.9	125326
31	3988	5900	1 403	143.7	72 2	19.83	7.56	.3191	.1675	5.058	3.11	.206	15.43	18.62	27.55	47.3	14.7	192.2	109874
32	4981	7004	.807	143.7	75.8	23.44	7.57	.3191	.1753	6.154	2.21	.155	15 81	18.28	25.84	51.6	14.7	189.7	128695
ASSUMED CARDS, VARIABLE NOZZLE PRESSURE																			
A	4050	5936	1.04	187.8	82.5	10.93	4.70	.4107	.1897	3.597	4.73	.474	12.00	17.69	25.92	39.7	7.0	218	105000
B	5590	8192	1 05	182.2	96.0	16 45	″	.3991	.2186	5.537	3.14	.268	12.18	15.45	22.63	46.0	10.0	″	126600
C	6710	9836	1.07	176 0	119.5	22.80	″	.3862	.2685	7.55	2.27	.156	13.62	15.98	23.40	52.2	13.5	″	157300
D	7370	10792	1 10	168.6	122 8	29.83	″	.3708	.2753	9.71	1.73	.087	16.30	17.72	25.95	58.5	18.0	″	191100
E	7740	11336	1.05	160 9	136.2	37.60	″	.3549	.3034	11.92	1.31	.033	18.91	19.54	28.61	64.7	23.0	″	221400
ASSUMED CARDS, CONSTANT NOZZLE PRESSURE																			
F	3875	5676	1 12	182.2	136.2	16.45	″	.3991	.3034	5.140	3 14	.268	16.31	20.69	30.30	64.7	16.0	″	117400
G	5795	8484	.988	176 0	″	22.80	″	.3862	″	7.374	2.27	.156	15.57	18.00	26.38	″	″	″	152700
H	7190	10540	.974	168 6	″	29 83	″	.3708	″	9.633	1.73	.087	16.45	17 88	26.20	″	″	″	188500
I	8200	12008	.958	160.9	″	37.60	″	.3549	″	11.92	1.31	.033	17.86	18.45	27.04	″	″	″	221700

TABLE 3 SERIES B

ASSUMED CARDS							L.P EXHAUST QUALITY DATA.				
NO	WATER p.Hr. Lbs.	H.P. STM. TO L.P. CYL %	MOISTURE at L.P. Adm %	ADM PR L P Abs Lbs/□"	REL PR. L. P Abs Lbs/□"	EXH PR L P Abs Lbs/□"	r	QUAL OF L.P. EXHAUST %	COMB. QUAL %	DRY STM. TURB. Lbs/Hr.	
A	105000	93.2	2.5	37	9.5		2.76	90.6	84.4	88600	VNP
B	126600	94.3	3.0	43	14.		2.47	90.9	85.7	108500	"
C	157300	95.2	3.5	49	19		2.26	91.4	86.9	136700	"
D	191100	95.9	4.0	55	24		2.10	91.6	87.8	167800	"
E	221400	96.2	4.0	60	28		1.98	91.9	88.4	195600	"
F	117400	96.8	3.0	60	20	17.5	3.30	90.8	84.5	99200	CNP
G	152700	95.7	3.5	"	20	"	2.94	90.5	85.5	130600	"
H	188500	94.4	4.0	"	23	"	2.46	90.8	86.9	163800	"
I	221700	93.1	4.0	"	27	"	1.98	91.6	88.7	196600	"

REMARKS & FORMULAE

TESTS 21–29 INCLUSIVE, 8 HRS.

TESTS 31–32, 8 HRS. ATMOSPHERIC EXHAUST NON-CONDENSING

$$\frac{IHP}{KW} = 1.465$$

$r = \frac{51.7}{V_a}$ for HP Card = Ratio of Expansion

$y = 0.129(r - 1.06)$ = Missing Water

ω = Sp. density @ p

$$W_a \times V_a = \overline{W_1} \qquad W_c \times V_c = \overline{W_2} \qquad \overline{W_1} - \overline{W_2} = \overline{W_3}$$

$$\frac{\overline{W_3} \times 60 \times 4 \times 75}{IHP} = IWR \text{ @ HP Cut-off}$$

$IWR \times (1 + y)$ = AWR/IHP/HR.

TABLE 4 SERIES B

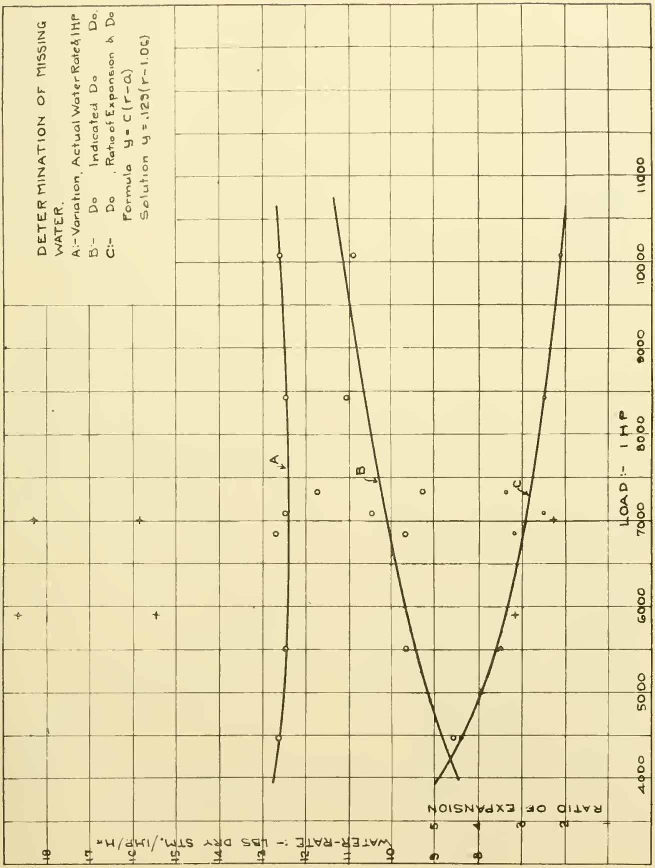


FIG. 4 SERIES B

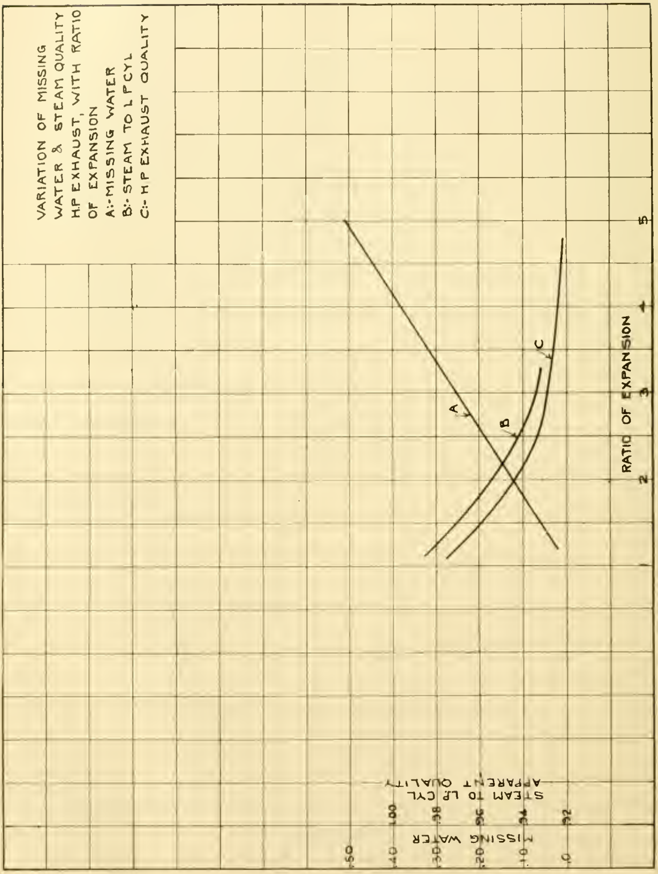


Fig. 5 Series B

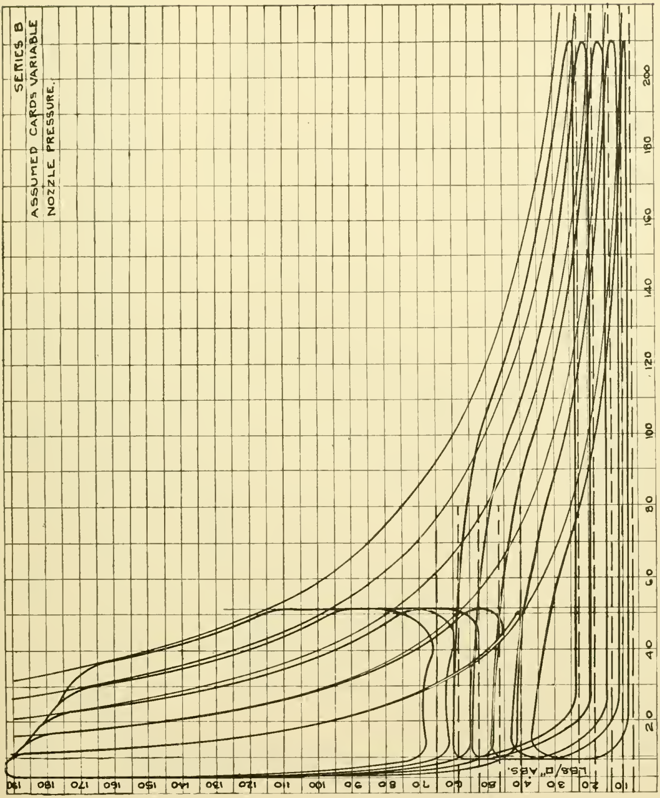


Fig. 6 Series B

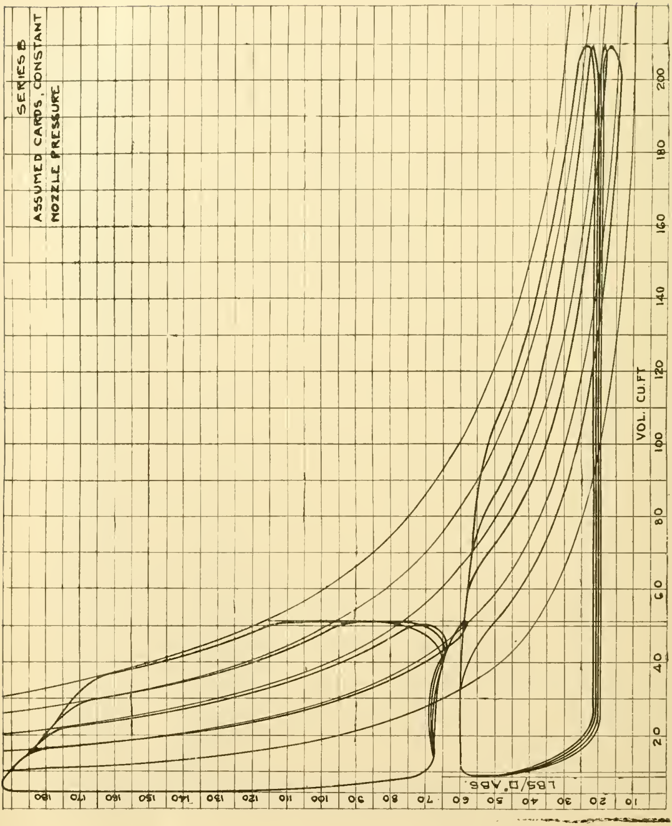


Fig. 7 Series B

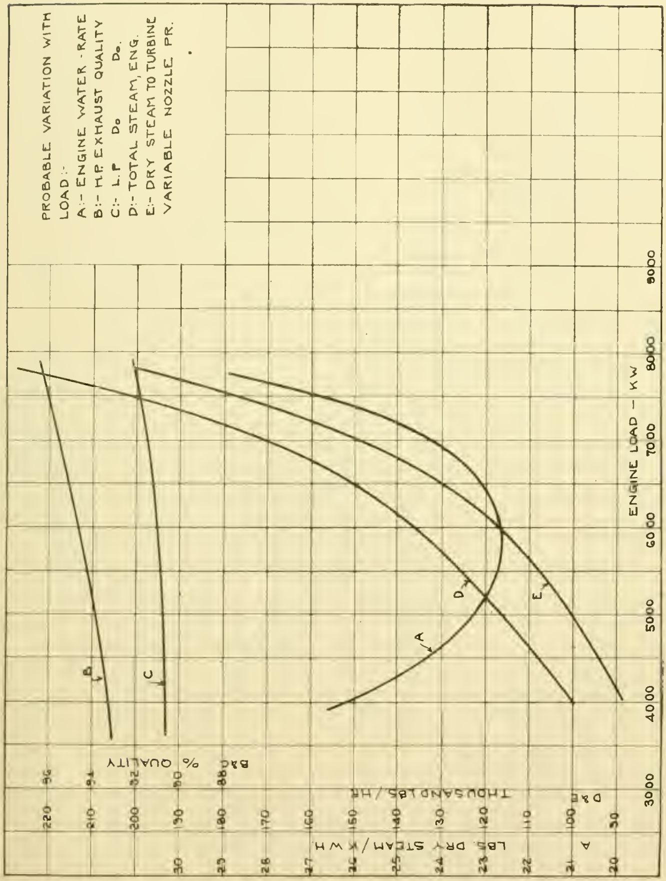


Fig. 8 Series B

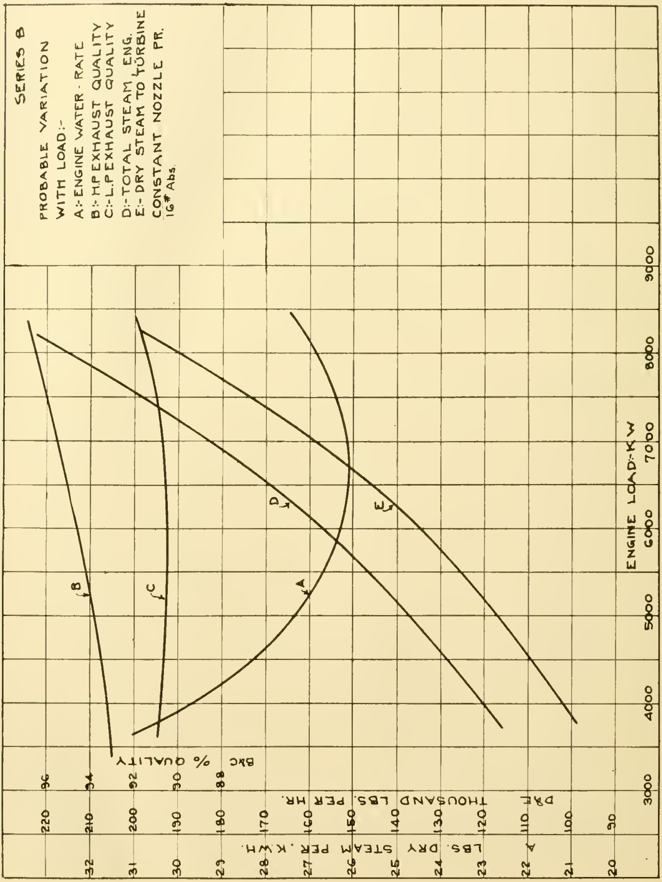


FIG. 9 SERIES B

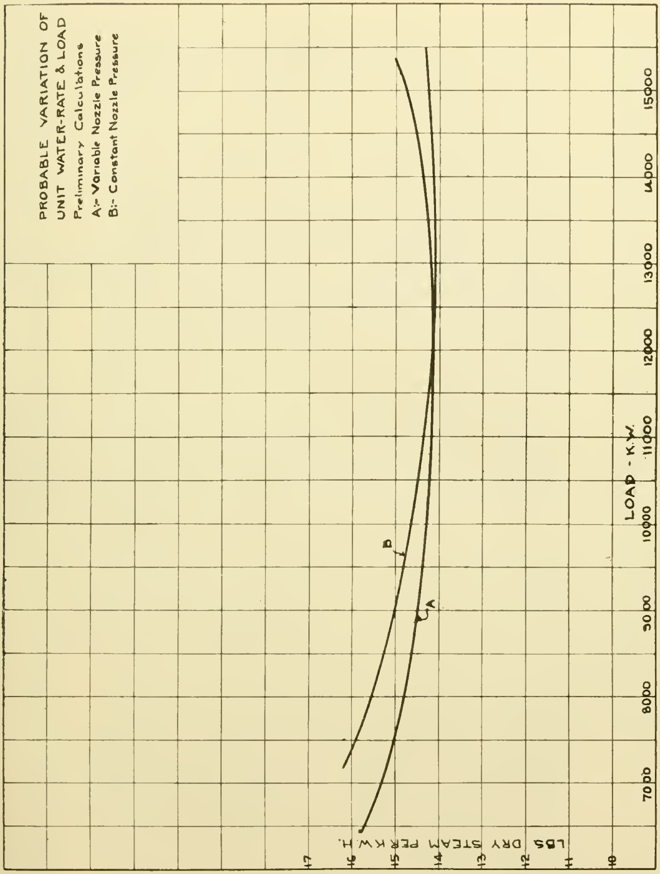


Fig. 10 Series B

RESUMÉ OF OBSERVATIONS — CORRECTED TO 29.92" BAR & 14.7# ATMOS.

TEST NUMBER	DURATION	LOADS			PRESSURES					QUALITIES		WATER			DRY STEAM		TEMPERATURES		
		UNIT	ENGINE	TURBINE	H.P. STEAM	RECEIVERS	L.P. STEAM	L.P. STEAM	VACUUM	H.P. STEAM	L.P. TURB	SEPARATOR L.P.	TURBINE DISCH.	TOTAL UNIT	TURBINE	ENG. & UNIT	HOT WELL COND	INJECTION	DISCH CIRC WATER
	Hours.	K.W.	K.W.	K.W.	Lbs. Gauge p.□"	Lbs. Gauge p.□"	Lbs Abs. p.□"	Lbs. Gauge p.□"	Ins. Hg.	%	%	Lbs. per Hour	Lbs. per Hour	Lbs per Hour	Lbs per Hour	Lbs per Hour	°F	°F	°F
5	4	10220	6627	3690	174.4	36.2	12.72	—	28.03	97.08	90.89	3369	150170	153540	136500	149000	88.1	72.1	84.0
6	5	11320	6520	4870	173.4	35.7	17.22	1.52	28.34	96.96	94.09	2759	167190	169950	158200	164850	87.6	74.7	87.8
7	3	11150	6187	4960	173.4	33.9	17.36	2.66	28.55	97.06	90.17	1157	164945	166100	148350	161200	85.5	72.5	86.0
8	3	10970	6178	4840	170.2	49.6	17.36	2.66	28.44	97.15	88.62	654	161612	162270	143200	157700	86.9	74.4	86.6
9	2	11250	6560	4685	170.2	50.1	16.61	1.91	28.18	97.08	92.08	5830	164458	170290	151900	165300	87.8	72.8	86.3
10	1	12440	7060	5400	172.0	49.3	17.60	2.90	27.91	97.54	86.96	3133	185100	188230	161400	183600	89.5	72.0	83.3
11	2	8990	5195	3795	172.0	50.0	16.61	1.91	27.92	97.54	91.32	469	136850	137320	124890	133930	87.3	72.4	83.5
12	1	13240	7580	5610	172.6	48.8	17.06	2.36	27.99	98.32	85.06	6018	192290	198310	163500	194900	90.7	75.4	89.2
13	2	10240	6070	4220	172.0	47.1	16.80	2.10	27.98	98.50	91.05	825	156470	157290	142470	154900	88.2	72.8	83.8
14	2	11480	6140	5340	174.8	51.4	18.84	4.14	28.29	98.41	90.24	337	176210	176550	159010	173740	86.4	73.0	86.6
15	5	11504	6022	5468	170.8	48.1	19.45	4.75	27.51	97.83	95.15	—	167103	—	159000	—	91.8	78.2	93.5
16	7	11526	6314	5203	173.9	48.4	19.45	4.75	27.42	98.02	93.57	9633	167085	176718	157300	173200	92.9	78.6	91.5
17	5	11528	6084	5488	175.7	49.5	19.90	5.20	27.62	97.70	94.68	5111	179170	184301	169650	180100	86.4	73.6	86.7
18	6	10740	5916	4831	174.1	49.5	18.56	3.86	27.65	98.19	94.83	12554	149148	161702	141450	158750	89.7	72.8	83.6
19	6	14540	7860	6692	174.0	51.7	18.42	3.72	27.78	97.66	95.07	16404	201351	217755	191450	212700	90.9	72.2	88.2
20	4	14365	7373	6962	171.6	52.2	20.94	6.24	27.75	97.88	96.47	15423	196680	212103	189750	207750	90.3	72.6	93.7
21	6	10320	5632	4617	175.9	49.8	17.77	3.07	28.03	97.54	89.52	6486	144399	150885	129150	147100	87.8	72.5	84.4
23	6	13410	7460	5862	173.9	50.2	18.01	3.31	27.72	97.80	96.09	15760	195514	211274	188000	206800	91.1	73.0	87.0
24	6	12927	7033	5820	169.8	50.2	18.59	3.89	27.79	98.03	95.47	14439	173150	187589	165300	183950	89.8	73.3	86.8
25	6	9730	5142	4508	175.3	49.7	18.99	4.29	27.78	97.77	96.46	11189	134635	145824	129840	142600	88.8	72.3	82.8
26	6	11840	6470	5305	172.6	49.2	19.02	4.32	27.48	98.18	96.48	14090	161983	176073	156300	172900	88.2	73.1	84.9
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

TABLE 5 SERIES C

RESULTS									GUARANTEE & CALCULATED WATER RATES			CIRC. WATER		WATER RATE, UNIT,	REMARKS	FORMULAE & NOTES
TEST	LOAD	WATER RATES (Dry Steam)														
		TURBINE ACTUAL	ENGINE ACTUAL	UNIT ACTUAL		UNIT Moist Corr.	UNIT Total Corr.		TURBINE Constant Nozzle Pr.	ENGINE Constant Nozzle Pr.	UNIT Constant Nozzle Pr.	RATIO	TOTAL	EQUIVALENT I.H.P.		
	K.W.	Lbs per K.W.H	Do	Do		Do	Do.		Do	Do.	Do.	C W / Dry St.	Gals per Minute	Lbs per I.H.P.Hr C.N.P		
5	10220	36.98	22.48	14.57		14.0	13.53		28.42	26.03	14.42	89.0	26740	8.85	Varying Nozzle Pressure	27 = 17 / 4+[1+(1-1E)]5
6	11320	32.34	25.30	14.45		14.1	13.94		27.30	26.04	14.07	80.5	26920	8.68	Auxiliary Steam Included C.N.P	
7	11150	30.42	26.05	14.49		13.85	13.90		27.22	26.07	14.10	78.3	25800	9.10	Constant Nozzle Pressure	28 = 27-(285-10
8	10970	29.58	25.51	14.37		13.64	13.70		27.31	26.07	14.15	86.5	27960	8.76	Do	
9	11250	32.42	25.20	14.69		14.23	13.55		27.42	26.04	14.09	79.0	25980	9.03	Do.	
10	12440	29.89	26.01	14.76		13.95	13.36		27.00	26.08	13.88	93.5	30560	8.27	V.N.P	
11	8990	32.91	25.79	14.89		14.36	13.78		28.29	26.99	15.10	94.5	25820	8.76	C.N.P	
12	13240	29.15	25.71	14.72		13.90	13.39		26.90	26.46	13.90	76.5	30320	8.25	Do	
13	10240	33.76	25.52	15.13		14.51	13.99		27.83	26.10	14.41	96.0	30200	9.01	Do.	
14	11480	29.78	28.30	15.15		14.47	14.26		27.02	26.10	14.03	78.6	25000	9.14	V.N.P	
15	11504	29.06	–	–		–	–		26.97	26.24	14.01	69.	23060	–	Aux. Included C.N.P.	
16	11526	30.22	27.42	15.02		14.64	13.56		27.10	26.12	14.01	82.	27400	8.93	C.N.P.	
17	11528	30.90	29.70	15.68		15.20	14.32		26.96	26.20	14.01	81.	29020	9.53	Aux Included V.N.P.	
18	10740	29.26	26.84	14.78		14.41	13.56		27.31	26.30	14.22	98.	29230	9.06	C.N.P.	
19	14540	28.60	27.05	14.62		14.30	13.58		26.63	26.69	13.80	66.	26560	9.08	Do.	
20	14365	27.23	28.15	14.45		14.25	13.50		26.60	26.31	13.80	51	20050	9.05	V.N.P	
21	10320	27.97	26.11	14.25		13.70	13.23		27.49	26.50	14.39	85.	24520	8.52	C.N.P.	
23	13410	32.05	27.70	15.41		15.25	14.47		26.81	26.37	13.80	75.5	29520	9.81	Do	
24	12927	28.40	26.14	14.22		14.0	14.29		26.82	26.16	13.81	78.5	27180	8.93	Do	
25	9730	28.81	27.73	14.65		14.53	13.81		27.57	27.07	14.67	101.	27200	9.33	Do	
26	11840	29.45	26.71	14.60		~~14.44~~	13.42		27.04	26.09	13.96	91.	24500	9.06	Do.	
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

TABLE 6 SERIES C

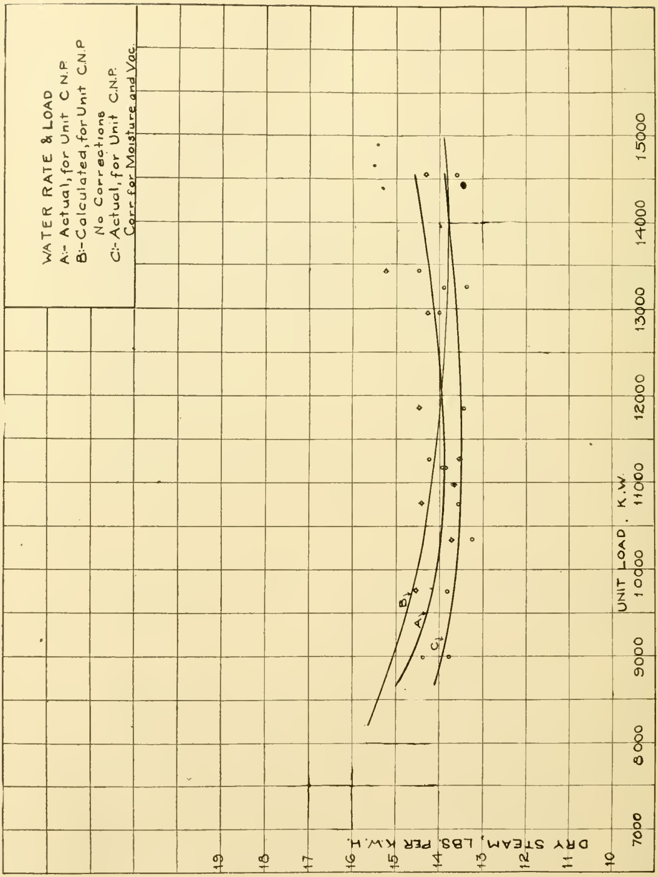


Fig. 11 Series C

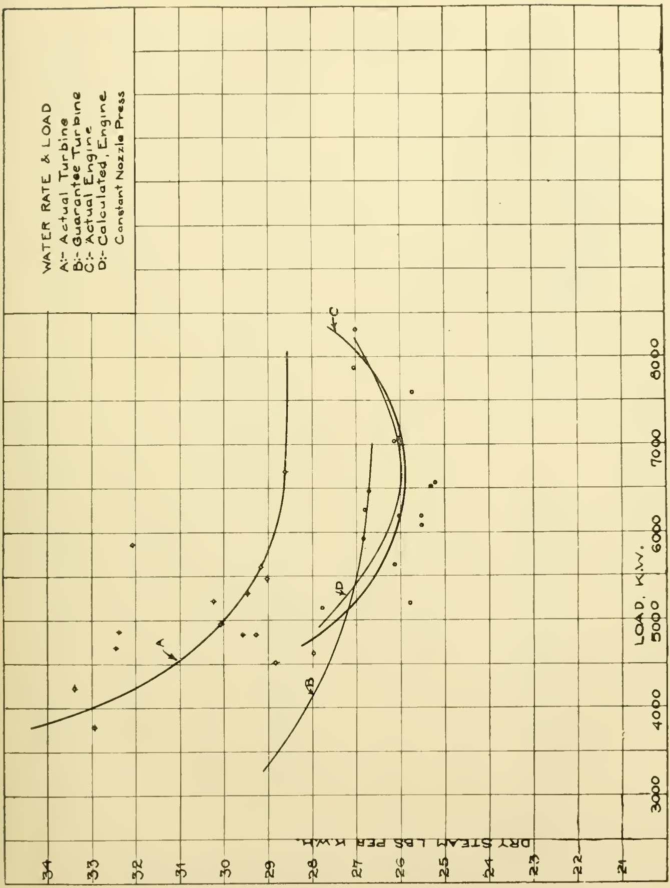


FIG. 11a SERIES C

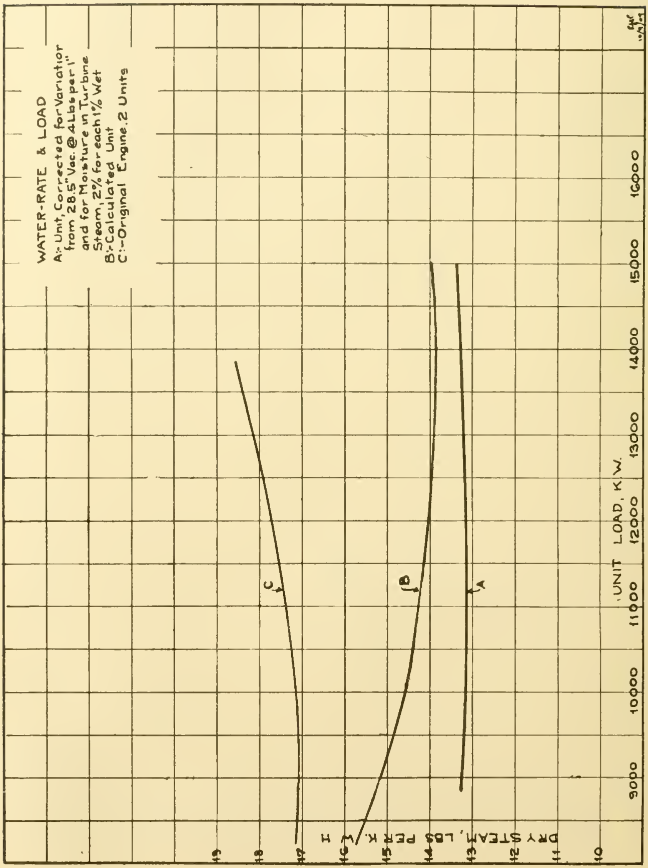


FIG. 11b SERIES C

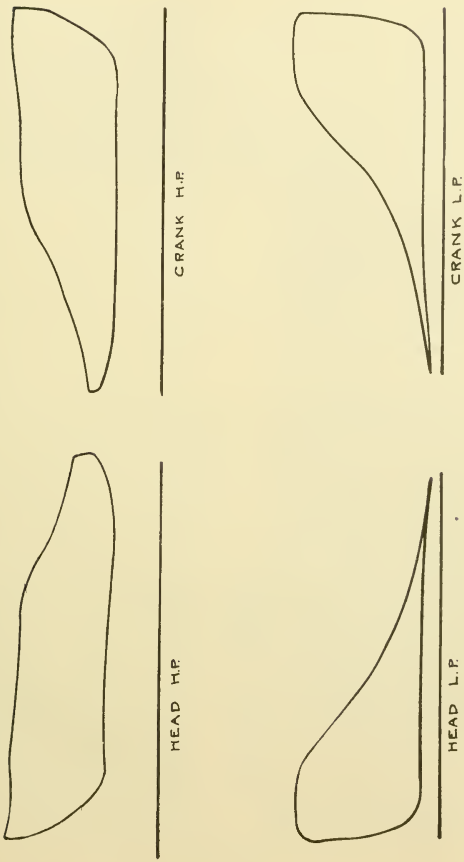


Fig. 12 Series C

TEST	DURATION Hrs	LOADS UNIT KW	ENG KW	TURB. KW	PRESSURES H.P. STM Lbs/□" Absolute	RECEIVERS Do	TURB STM. Do	VACUUM Do	VAC 29.92" Barom "Hg	QUALITIES HP STM %	TURB STM %	WATER Lbs/Hr TOTAL CONDENSATION	TURB WATER	TOTAL WATER UNIT	DRY STEAM TURBINE	ENG.& UNIT	TEMPERATURES COND. HOT WELL °F	CIRC W INJECTION °F	CIRC W DISCH. °F
27	6	9567	4875	4683	185.1	64.7	18 14	.70	28 50	99 0	93.4	8636	133840	142476	125000	141100	78 6	38.80	58 60
28	6	10527	5819	4714	189.8	64 9	16.93	.87	28.15	99 6	95.2	8570	146730	155300	139700	154700	80.4	39.53	67.04
29	2	11400	6410	5000	184.7	65 2	17.62	1 05	27.87	98 9	97.3	9601	162475	172076	158100	170300	81.3	37.40	67.77
30	4	11365	6590	4810	185.6	64.9	17 62	1.15	27.58	99.0	97.8	10088	161351	171439	157800	169700	84 5	39 20	73.90
31	6	12300	6930	5373	192.0	65 5	17 59	.90	28 12	99.3	97.8	11006	166826	177832	163200	176800	78.64	36.54	66 00
32	6	13160	7490	5717	193.4	66 3	17 66	95	27.98	99 5	97.2	12142	179776	191918	174700	191000	75.34	35 70	69 72
33	4	16085	8505	7670	192.3	65.2	20.00	1 12	27.64	99 8	94.7	7312	247090	254402	234000	254000	86.44	35 05	73.41
34	6	14223	8183	6060	192.3	65.8	17.56	1.11	27.66	99.4	95.7	9361	206261	215622	197500	214300	89.06	34 88	74 30
35	4	13295	7783	5524	194.7	65.8	17 13	1.20	27.49	99.5	95.4	11145	187214	198359	178600	197500	90.85	35 22	76.39
36	5	12217	7169	5033	192 7	64 3	16.28	1.05	27.78	99.8	93.8	13017	165908	178925	155500	178700	89 42	34 66	70.76
37	6	10043	5813	4184	190.4	63 9	16 40	1.02	27.84	99.4	93.7	9823	140932	150755	132000	149800	91 80	36 67	70.72

TEST	ACTUAL WATER-RATES ENG.	TURB	UNIT	CORRECTED UNIT MOISTURE	MOIST-& VAC	I H.P ENGINE HP	L P	TOTAL	FACTOR IHP/KW
27	28.94	27.65	14.75	14.30	14.30	3861	3502	7363	1.511
28.	26.69	30.15	14.68	14.37	14.02	4138	4359	8497	1.461
29	26.57	31.62	14.94	14.74	14.11	4445	4712	9157	1.429
30	25.74	32.81	14.93	14.74	18.82	4477	4727	9204	1.397
31	25.49	30.38	14.36	14.22	13.74	4753	5045	9798	1.414
32	25.50	30.57	14.51	14.29	13.77	5092	5583	10675	1.425
33	29.86	30.50	15.79	15.32	13.46	5902	6229	12131	1.426
34	26.18	32.60	15.07	14.78	13.94	5585	6018	11603	1.417
35	25.38	32.34	14.85	14.56	13.55	5246	5682	10928	1.404
36	24.92	30.91	14.62	14.29	13.57	4873	5421	10294	1.435
37	25.77	31.54	14.93	14 60	13.94	4248	4312	8560	1.473

TABLE 7 SERIES D

NO. TEST	DATE 1910	DURATION Hrs.	LOADS: TOTAL UNIT K.W.	LOADS: ENGINE K.W.	LOADS: TURBINE K.W.	PRESSURES: MN. STEAM Abs. Lbs/□"	MN. STM. Gge Lbs/□"	RECEIVERS Abs. Lbs/□"	REC. Gge. Lbs/□"	L.P. SEPARATOR Abs. Lbs/□"	L.P. SEP. Gge Lbs/□"	L.P. SEP. U Tube "Hg.	VACUUM Hg. Col. "Hg.	VAC. Absolute Manom. "Hg. Ab	VAC. Abs. Lbs Abs	BAROMETER "Hg.	STD VAC. 29.92" Bar "Hg.	C.W. PUMP SUCTION "Hg	C.W. PUMP DISCHARGE Gge Lbs/□"
38	Jan 11	5	16172	8384	7784	197.0	182.3	64.2	49.5	20.60	5.90	10.94	29.30	1.50	.74	30.63	28.42	12.7	12.0
39	11	5	13485	7798	5895	203.8	189.1	64.5	49.8	16.50	1.80	2.61	29.10	1.58	.78	30.59	28.34	12.2	12.9
40	12	5	13038	7314	5711	196.1	181.4	63.8	49.1	16.20	1.50	1.82	29.46	1.22	.60	30.61	28.72	11.0	12.8
41	12	5	12284	6938	5348	200.2	185.5	64.5	49.8	16.10	1.40	2.18	29.32	1.31	.64	30.57	28.69	12.6	12.1
42	13	5	11252	6248	4938	197.0	182.3	64.0	49.3	16.24	1.54	2.20	29.41	1.32	.65	30.65	28.60	9.9	14.3
43	13	5	10476	5824	4602	198.0	183.3	63.8	49.1	16.20	1.50	2.00	29.23	1.46	.72	30.58	28.46	12.6	12.8
44	14	5	9408	4940	4426	198.8	184.1	63.8	49.1	16.10	1.40	2.28	29.47	.93	.46	30.31	28.99	9.5	11.6
45	14	1 3/4	9712	5916	3709	198.2	183.5	64.3	49.6	10.50		-7.48	28.96	1.22	.60	30.21	28.70	11.6	11.6
46	15	1/2	12700	7180	5640	198.5	183.8	62.6	47.9	12.96		-2.78	29.45	1.03	.51	30.32	28.89	13.75	9.5
47	15	1/2	11940	7060	4780	195.3	180.6	62.6	47.9	12.35		-1.80	29.72	1.03	.51	30.32	28.89	12.9	9.9
48	15	3	9306	5865	3323	196.3	181.6	63.8 46.3	49.1 31.6	9.65		-10.49	29.13	1.20	.59	30.33	28.72	12.0	10.6
49	15	1	10940	6640	4300	194.9	180.2	49.3	35.6	11.65		-6.62	29.19	1.13	.56	30.32	28.79	12.1	10.9
50	15	4	15498	8169	7260	192.0	177.3	59.0	44.3	17.80	3.10	3.54	29.23	1.13	.56	30.32	28.79	14.6	10.4
51	17	3	11240	6753	4376	194.0	179.3	55.0	40.3	11.50		-6.71	29.25	1.19	.58	30.38	28.73	11.5	9.9
52	17	3	7200	4743	2400	196.5	181.8	41.5	26.8	7.97		-14.92	29.07	1.29	.63	30.29	28.63	10.6	10.7
53	17	3	11927	7070	4834	199.0	184.3	52.9	38.2	12.75		4.58	29.10	1.25	.61	30.26	28.67	13.2	10.1
54	26	3	14173	7820	6283	193.4	178.6	55.7	40.9	15.18	.48	1.04	29.31	.93	.46	30.03	28.99	10.1	9.5
55	26	3	8347	5403	2910	197.4	182.7	43.0	28.3	8.21		-13.48	28.90	1.15	.57	29.97	28.77	12.4	9.0
56	26	3	13033	7457	5550	197.2	182.5	54.3	39.6	14.09		-1.75	29.01	1.01	.50	29.90	28.91	13.2	9.4
57	27	3	14580	7960	6583	199.7	179.2	59.6	45.1	15.57	.87	+3.04	28.85	.85	.42	29.49	29.07	10.3	8.8
58	27	3	6673	4420	2213	197.7	183.2	40.1	25.6	7.08		-15.14	28.48	.98	.48	29.48	28.94	12.6	8.6
59	27	3	10007	6194	3804	199.1	184.6	47.3	32.0	10.35		-8.59	28.55	.94	.46	29.50	28.98	14.3	8.7
60	28	3	11820	6923	4860	195.1	180.5	51.6	36.9	12.10		-4.98	28.96	.87	.43	29.79	29.05	10.7	10.4
61	28	3	11480	6587	4893	196.8	182.2	51.4	36.7	12.34		-4.46	28.88	1.00	.49	29.79	28.92	12.4	10.2
62	28	3	15860	8440	7410	195.0	180.4	63.4	48.8	17.84	3.14	7.60	28.73	1.19	.58	29.79	28.73	13.9	9.9

TABLE 8 SERIES E AND F

NO. TEST	LOAD	HP THROTTLING CALRIM.				#1 SEPARATING.			#2 SEPARATING			#1 THROTTLING				#2 THROTTLING		
		AV. MN STM. TEMP.	CAL. DISCH. TEMP	CAL. DISCH. PRESS. Gauge	QUAL.	MOISTURE	FLOW	QUAL.	MOISTURE	FLOW	QUAL.	STM. TEMP.	DISCH. TEMP.	DISCH. PRESS. Vacuum	QUAL.	DISCH. TEMP.	DISCH. PRESS. Vacuum	QUAL.
	KW	°F	°F	"Hg.	%	Lbs.	Lbs.	%	Lbs.	Lbs.	%	°F	°F	"Hg.	%	°F	"Hg	%
38	16172	380.6	312.1	18.27	99.5	11.55	153.43	92.9				229.2	198.4	17.76	99.2			
39	13485	383.4	282.0	25.68	97.9	10.49	117.59	91.8				217.6	184.2	20.31	98.8			
40	13038	380.2	302.9	21.81	99.2	10.10	119.41	92.2				216.7	182.0	20.74	98.8			
41	12284	381.9	297.5	19.80	98.9	9.88	119.93	92.4				216.3	180.3	20.55	98.7			
42	11252	380.6	294.8	20.77	98.7	9.73	120.16	92.6	1.42	18.77	93.0	216.7	181.5	20.60	98.7	164.0	26.12	98.1
43	10476	381.0	291.8	20.42	98.5	8.86	111.94	92.6	3.18	46.47	93.6	216.7	182.9	21.50	98.8	168.9	26.23	98.4
44	9408	381.3	297.9	21.78	98.7	8.05	99.50	92.5	1.08	18.90	94.6	216.4	179.3	21.55	98.6	177.0	25.71	98.5
45	9712	381.1	294.8	21.92	98.7	1.10	14.10	92.8	.79	11.95	93.8	195.4	172.5	23.70	99.2	159.5	27.37	98.6
46	12700	381.2	296.7	21.40	98.8	.43	10.60	96.1	.16	4.00	96.2	210.2	170.3	21.30	98.4	163.9	26.40	98.3
47	11940	379.9	304.0	20.63	99.1	.29	9.10	96.9	.16	3.60	95.8	203.3	176.0	22.48	98.9	165.7	26.72	98.6
48	9306	380.3	290.5	21.18	98.6	2.43	42.25	94.6	1.22	16.88	93.3	191.8	171.2	24.29	99.3	156.9	27.42	98.6
49	10940	379.7	299.0	21.05	98.9	.74	16.77	95.7	.41	6.90	94.4	200.3	178.3	22.62	99.3	167.3	26.76	98.7
50	15498	378.5	305.6	19.77	99.4	2.84	70.70	96.2	1.27	41.56	97.0	221.4	189.4	19.89	98.8	182.9	25.40	98.6
51	11240	379.4	292.6	21.93	98.6	2.04	51.67	96.2	1.15	19.96	94.5	199.8	174.8	22.68	99.0	165.0	27.04	99.1
52	7200	380.4	288.8	20.71	98.4	2.04	36.77	94.7	.93	14.05	93.7	182.4	163.0	25.21	99.3	148.0	27.75	98.6
53	11927	381.4	294.4	20.64	98.6	1.79	56.20	95.3	1.11	21.66	95.1	204.7	177.0	21.96	99.0	168.8	26.73	98.7
54	14173	379.1	296.9	22.41	98.9	2.13	56.70	96.3				213.3	191.4	19.92	99.4			
55	8347	380.8	292.9	20.87	98.6	1.57	38.91	96.1				184.2	165.2	24.20	99.3			
56	13033	380.7	298.2	20.25	98.7	1.63	61.64	97.4				209.7	184.9	20.81	99.1			
57	14580	379.2	298.8	21.75	99.0	2.06	70.87	97.2				215.3	188.9	18.77	99.0			
58	6673	380.9	298.4	21.80	99.0	1.79	33.30	94.9				178.4	161.1	24.41	99.4			
59	10007	381.5	287.0	21.53	98.2	2.62	47.12	94.7				194.8	171.1	22.70	99.2			
60	11820	379.8	299.9	21.34	99.0	1.56	54.77	97.2				202.4	175.0	21.67	99.0			
61	11480	380.5	302.8	21.00	99.1	1.55	55.79	97.3				203.3	178.4	21.57	99.0			
62	15860	379.7	299.7	20.63	99.0	2.19	80.02	97.3				221.9	197.6	17.87	99.3			

TABLE 9 SERIES E AND F

NO. TEST	THOMAS CALORIMETER: WATT HRS.	THOMAS CALORIMETER: STM. TEMP.	THOMAS CALORIMETER: CAL DISCH. TEMP	THOMAS CALORIMETER: CAL DISCH WATER	THOMAS CALORIMETER: QUAL	#1 COMB. QUAL.	#2 COMB. QUAL.	AVGE QUAL.	EXHAUST FROM ENGINE: SEPARATING CAL.: MOISTURE	SEPARATING CAL.: FLOW	SEPARATING CAL.: QUAL.	THROTTLING CAL.: STM. TEMP	THROTTLING CAL.: CAL. DISCH TEMP	THROTTLING CAL.: CAL. DISCH. PRESS.	THROTTLING CAL.: QUAL.	COMB QUAL.	QUAL. by Separator Water × Turb Stm Qual.
	WH	°F	°F	Lbs	%	%	%	%	Lbs.	Lbs.	%	°F	°F	Vac "Hg	%	%	%
38	6600	229.2	414.6	93.90	84.1	92.2		90.2									
39	5623	217.6	430.6	84.10	86.3	90.7		89.4									
40	4758	216.7	429.9	93.60	92.4	91.1		91.5									
41	3242	216.3	412.7	70.20	93.2	91.2		91.9									
42	4268	216.7	426.8	110.20	94.4	91.4	91.2	93.0									
43	5000	216.7	408.3	116.50	94.3	91.5	92.1	92.6									
44	4575	216.4	424.6	88.80	91.9	91.2	93.2	92.1									
45	1519	195.4	445.2	30.90	94.9	92.0	92.5	93.1									
46	500	210.2	356.9	20.40	98.5	94.6	94.6	95.9									
47	350	203.3	454.2	27.40	95.6	95.8	94.5	95.3									
48	2100	191.8	420.0	37.92	91.7	93.9	92.0	92.5									
49						95.0	93.2	94.1									
50	2377	221.4	346.5	81.70	95.8	95.0	94.4	95.1									
51	2100	199.8	420.7	47.70	95.4	95.2	93.6	94.7									
52	2300	182.4	395.5	58.40	96.5	94.0	92.4	94.3									
53	2500	204.7	433.2	59.00	96.2	94.3	93.8	94.8									
54	650	213.3	276.7	44.05	98.0	95.7		96.9	2.53	26.90	91.4	213.8	180.5	23.29	98.7	90.2	89.6
55	600	184.2	293.6	28.10	97.4	95.4		96.4	2.05	15.17	88.1	185.6	148.7	26.71	98.5	86.8	90.2
56	600	209.7	268.5	44.40	98.1	96.5		97.3	2.53	21.70	89.5	209.5	167.7	25.41	98.6	88.2	90.3
57	600	215.3	260.8	56.10	98.4	96.2		97.3	1.92	21.40	91.8	216.2	172.1	25.16	98.4	90.3	89.3
58	450	178.4	267.7	24.90	97.0	94.4		95.7	1.88	17.12	90.7	177.9	148.3	25.80	98.8	89.0	89.7
59	600	194.8	265.5	32.80	97.2	94.0		95.6	2.28	15.72	87.3	195.3	154.0	26.02	98.5	86.0	89.8
60	600	202.4	274.2	39.90	98.2	96.3		97.3	2.49	19.17	88.6	203.4	163.4	25.76	98.5	87.3	90.3
61	600	203.3	272.8	41.40	98.3	96.3		97.3	2.34	16.95	87.9	204.1	160.1	26.07	98.3	86.4	91.2
62	700	221.9	274.3	55.40	98.1	96.6		97.4	2.11	24.65	92.1	222.8	178.4	24.73	98.5	90.7	89.8

TABLE 10 SERIES E AND F

TEST	WEST MN STM.	EAST MN STM	AVGE MN STM	WEST RECEIVER	EAST REC	AVGE. REC.	EAST ENG EXH.	EAST SEPARATOR INLET	SEPARATOR OUTLET	TURBINE BOWL	CONDENSER	HOT WELL WATER	CIRC. WATER INJECTION	CIRC. WATER DISCHARGE
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
38	381.0	380.2	380.6	297.0	297.4	297.2	230.5	230.1	229.2	228.5	90.90	71.20	37.66	57.28
39	384.1	382.8	383.4	297.3	297.4	297.4	218.7		217.6	217.0	94.60	76.23	39.85	62.51
40	380.3	380.1	380.2	296.1	297.5	296.8	218.0	217.6	216.7	216.1	84.45	70.97	32.03	51.84
41	382.4	381.4	381.9	297.0	297.7	297.3	217.9	217.2	216.3	216.3	87.17	73.41	33.95	56.76
42	380.2	380.9	380.6	296.9	297.0	297.0	218.6	218.6	216.9	216.9	87.18	75.25	31.82	56.67
43	380.6	381.3	381.0	296.8	296.6	296.7	217.9		216.7	216.3	89.32	80.17	32.75	57.14
44	380.3	382.2	381.3	296.9	296.5	296.7	217.6		216.4	216.1	73.87	59.42	31.63	41.98
45	380.3	381.8	381.1	296.8	297.7	297.3	208.2		195.4	196.7	86.72	66.20	32.22	43.97
46	379.7	382.7	381.2	295.0	296.0	295.5	209.0		210.2	208.0	77.20	63.70	40.20	53.10
47	378.0	380.8	379.9	295.3	296.0	295.6	205.0		203.3	204.0	80.00	63.00	36.00	46.85
48	379.6	381.0	380.3	297.1 276.3	296.4 275.8	296.7 276.1	193.7 190.5		191.8	192.5 189.4	84.86	60.58	32.90	42.06
49	377.8	381.6	379.7	279.6	280.4	280.0	202.0		200.3	201.0	83.50	62.60	31.38	53.86
50	376.7	380.2	378.5	291.5	291.5	291.5	222.6		221.4	221.0	82.23	65.69	31.51	50.08
51	379.0	379.8	379.4	287.2	286.8	287.0	203.4		199.8	199.8	83.16	65.18	37.50	43.10
52	379.7	381.0	380.4	268.9	270.2	269.6	183.8		182.4	180.8	85.70	58.15	31.47	39.81
53	380.5	382.3	381.4	285.5	283.2	284.4	205.7		204.7	204.6	83.65	65.65	31.46	45.37
54	376.3	381.8	379.1	287.1	288.7	287.9	215.6		213.3	213.3	81.20	57.26	33.54	47.77
55	378.0	383.5	381.8	271.8	271.7	271.7	187.0		184.2	183.8	81.00	58.64	33.08	41.30
56	378.4	383.0	380.7	285.8	286.5	286.2	209.3		209.7	207.6	74.70	60.72	33.40	50.10
57	377.0	381.4	379.2	293.0	291.6	292.3	217.5		214.9	215.5	67.41	53.21	33.28	47.60
58	379.4	382.5	380.9	267.5	267.9	267.7	177.4		177.4	176.3	78.20	53.85	33.18	39.46
59	380.0	383.0	381.5	277.5	277.4	277.5	195.7		194.8	194.1	78.30	59.12	33.40	43.66
60	377.9	381.7	379.8	283.2	283.0	283.1	204.4		202.4	202.4	74.04	59.60	33.25	46.00
61	378.5	382.4	380.5	283.0	282.5	282.8	205.0		203.3	203.2	77.18	61.74	33.06	47.23
62	377.5	381.8	379.7	296.3	296.3	296.3	223.9		221.9	221.8	82.42	62.79	33.64	56.00

TABLE 11 SERIES E AND F

NO	LOAD K.W.	WATER PER HOUR: TURB. WAT. WGHD LBS PER HR	TURB WAT. VENTURI LBS PER HR	SEP. & TRAPS WGHD LBS PER HR	SEP WATER LBS PER HR	TRAPS VENTURI LB PER HR	TOT ENG WATER LBS PER HR	DRY STM ENG LBS PER HR	DRY STM TURB. LBS PER HR	WATER RATES: ACT. UNIT LBS PER K.W.HR	ACT ENG LBS PER K.W.HR	ACT. TURB. LBS PER K.W.HR	CORR UNIT MOIST ONLY LBS PER K.W.HR	CORR UNIT TOTAL CORR. LBS PER K.W.HR		I.H.P.: AV HP. I.H.P.	AV L.P I.H.P.	TOTAL I.H.P.	FACTOR IHP/KW
38	16172	237480		7425	7175	250	244905	243700	214200	15.07	29.54	27.51	14.40	14.10		5640	6117	11757	1.404
39	13485	187193		9883	5881	4002	197076	193000	167400	14.32	24.76	28.38	13.48	13.10		5104	5847	10951	1.404
40	13038	170661		12271	6281	5980	182932	181500	156200	13.92	24.78	27.35	13.44	13.42		4931	5650	10581	1.447
41	12284	160229		12064	3628	8436	172293	170400	147200	13.88	24.57	27.51	13.39	13.28		4800	5306	10106	1.457
42	11252	147142		10927	2607	8320	158069	156100	136900	13.87	24.99	27.72	13.54	13.42		4250	4330	8580	1.374
43	10476	138766		9939	1801	7138	147153	145000	128500	13.85	24.90	27.91	13.47	13.21		4227	4280	8507	1.460
44	9408	122689		8387	227	8160	131076	129400	113000	13.75	26.19	25.53	13.32	13.59		3771	3490	7261	1.470
45	9712	121870		13160	4910	8250	135030	133300	113500	13.72	22.53	30.59	13.49	13.45		3819	4367	8186	1.385
46	12700	160960		18874	11242	7632	179834	177700	154400	13.99	24.75	27.38	13.62	13.77		4994	6313	11307	1.575
47	11940	142740		17385	8935	8450	160125	158700	136800	13.30	22.49	28.45	13.15	13.31		4675	5736	10411	1.475
48	9306	114372		12555	4744	7811	126927	125100	105800	13.44	21.34	31.84	13.25	13.25		4129	4321	8450	1.441
49	10940	134785		16565	8257	8308	151350	149100	126900	13.69	22.40	29.50	13.39	13.46		5039	4545	9584	1.444
50	15498	202656		19161	16661	2500	221817	220400	192900	14.22	26.99	26.55	13.96	14.03		5784	5825	11609	1.421
51	11240	133462		16689	8399	8290	150151	148100	126500	13.19	21.95	28.89	13.04	13.04		4585	5244	9829	1.456
52	7200	89158		10861	7170	3691	100019	98400	84080	13.67	20.75	35.04	13.52	13.43		3662	3478	7140	1.505
53	11927	143897		17901	8164	9737	161798	159500	136500	13.38	22.57	28.22	13.13	13.08		4995	4897	9892	1.400
54	14173	176565		19180	12930	6250	195745	193600	171050	13.66	24.75	27.22	13.54	13.81		5430	5370	10800	1.400
55	8347	99210		13733	6183	7550	112943	111400	95620	13.34	20.60	32.85	13.23	13.28		3907	3792	7699	1.425
56	13033	158112		18849	11159	7690	176961	174700	153850	13.40	23.43	27.72	13.28	13.47		5115	5120	10235	1.373
57	14580	182508		20011	14741	5270	202599	200700	177600	13.75	25.19	26.95	13.65	14.00		5376	5673	11049	1.388
58	6673	81533		11225	4900	6325	92958	91800	78000	13.76	20.78	35.27	13.65	13.87		3282	3170	6452	1.460
59	10007	120863		14578	6478	8100	135441	133050	115600	13.30	21.48	30.38	13.13	13.39		4452	4294	8746	1.413
60	11820	141930		17833	9873	7960	159763	158200	138100	13.38	22.84	28.41	13.28	13.61		5108	4796	9904	1.431
61	11480	143958		17101	8791	8310	161059	159600	141500	13.92	24.45	24.22	13.75	13.95		4728	4594	9322	1.414
62	15860	206603		19762	15705	4057	226365	224200	201300	14.14	26.58	26.56	13.99	13.99		5750	6538	12288	1.456

TABLE 12 SERIES E AND F

NO. TEST	TOT. LOAD KW	SUPPLIED TO UNIT BTU	SUPPLIED TO UNIT %	SUPPLIED TO TURB ONLY BTU	SUPPLIED TO TURB ONLY %	ENG. K.W. OUTPUT BTU	ENG. K.W. OUTPUT %	TURB. K.W. OUTPUT B.T.U	TURB. K.W. OUTPUT %	TOTAL K.W. OUTPUT BTU	TOTAL K.W. OUTPUT %	TO CONDENSER BTU	TO CONDENSER %	TO HOT WELL BTU	TO HOT WELL %	LOST BY RADIA. ETC. BTU	LOST BY RADIA. ETC. %
		B.T.U. DISTRIBUTION : UNIT 15 1000000 B.T.U.															
38	16172	292.0	100	252.5	86.5	28.61	9.8	26.58	9.1	55.19	18.9	216.6	74.2	9.31	3.2	10.89	3.7
39	13485	232.6		196.6	84.6	26.36	11.3	19.88	8.6	46.27	19.9	168.4	72.4	8.28	3.6	9.64	4.1
40	13038	218.0		182.5	83.7	24.97	11.5	19.49	8.9	44.46	20.4	156.4	71.7	6.65	3.1	10.53	4.8
41	12284	204.7		171.8	83.9	23.67	11.6	18.25	8.9	41.92	20.5	146.9	71.7	6.64	3.2	9.23	4.5
42	11252	187.7		159.5	85.0	21.35	11.4	16.95	9.0	38.37	20.5	136.2	72.5	6.36	3.4	6.85	3.7
43	10476	174.5		149.8	85.9	19.93	11.4	15.76	9.0	35.68	20.5	127.3	73.0	6.69	3.8	4.77	2.7
44	9408	155.8		131.9	84.6	16.87	10.8	15.12	9.7	32.09	20.6	113.4	72.7	3.36	2.2	7.03	4.5
45	9712																
46	12700																
47	11940																
48	9306	150.5		122.3	81.3	20.14	13.4	11.46	7.6	31.61	21.0	107.6	71.5	3.27	2.2	8.06	5.4
49	10940																
50	15498	264.2		224.2	84.8	27.95	10.6	24.85	9.4	52.56	19.9	192.5	72.8	6.83	2.6	12.05	4.6
51	11240	178.0		146.0	81.8	23.16	13.0	15.05	8.4	37.85	21.3	126.5	70.9	4.43	2.5	8.84	5.0
52	7200	118.4		96.41	81.4	16.25	13.7	8.26	7.0	24.37	20.6	85.8	72.5	2.33	2.0	5.74	4.8
53	11927	191.8		157.8	82.3	24.16	12.6	16.53	8.6	40.66	21.2	136.4	71.2	4.84	2.5	9.84	5.1
54	14173	232.4		197.8	83.4	26.76	11.3	21.53	9.1	48.29	20.4	171.8	72.4	4.46	1.9	7.84	3.3
55	8347	133.8		109.55	81.9	18.48	13.8	9.97	7.5	28.45	21.3	97.9	73.2	2.64	2.0	5.77	4.3
56	13033	210.0		175.5	83.6	25.46	12.1	18.97	9.0	44.43	21.2	151.9	72.3	4.54	2.2	9.04	4.3
57	14580	240.7		205.4	85.4	27.20	11.3	22.51	9.4	49.74	20.7	179.0	74.4	3.87	1.6	8.10	3.4
58	6673	110.4		89.25	80.9	15.13	13.7	7.59	6.9	22.73	20.6	79.8	72.4	1.78	1.6	6.02	5.5
59	10007	160.0		133.6	83.2	21.13	13.2	12.99	8.1	34.12	21.3	116.7	72.9	3.28	2.1	5.87	3.7
60	11820	189.8		158.9	83.7	23.67	12.5	16.62	8.8	40.29	21.2	138.4	72.9	3.92	2.1	7.23	3.8
61	11480	191.8		161.5	84.2	22.47	11.7	16.70	8.7	39.17	20.4	140.5	73.3	4.28	2.2	7.83	4.1
62	15860	269.2		232.2	86.3	28.82	10.7	25.31	9.4	54.11	20.1	200.5	74.5	6.36	2.4	8.18	3.0

TABLE 13 SERIES E AND F

NO. TEST	LOAD UNIT	RANKINE EFFICIENCIES ENG. %	RANKINE EFFICIENCIES TURB %	RANKINE EFFICIENCIES UNIT %	THERM EFFIC REF'D TO RANKINE ENG %	THERM EFFIC REF'D TO RANKINE TURB %	THERM EFFIC REF'D TO RANKINE UNIT %	THERMAL EFF RECOV HW. WATER ENG %	THERMAL EFF RECOV HW. WATER TURB %	THERMAL EFF RECOV HW. WATER UNIT %	HEAT TO COND RATIO CW/ST.	HEAT TO COND B.T.U. per □"/Sec.	HEAT TO COND B.T.U. per □"/Sec. per °Rise	REMARKS
38	16172	16.7	18.2	30.1	70.3	60.0	65.0	11.7	10.9	19.5	53.5	2.58	.0594	C.N.P. Auxiliaries Exhaust to Heaters
39	13485	16.8	16.8	29.1	81.5	63.5	70.5	13.7	10.7	20.5	48.2	1.99	.0459	Do. " " "
40	13038	17.8	18.4	30.8	76.9	60.0	68.5	13.7	11.0	21.1	52.9	1.8.6	.0437	Do. " " "
41	12284	17.6	17.7	30.4	78.5	62.3	69.7	13.8	11.0	21.2	46.4	1.77	.0428	Do. " " "
42	11252	17.4	17.8	30.3	76.4	61.8	70.1	13.6	11.0	21.2	42.7	1.65	.0384	Do. " " "
43	10476	17.3	17.7	30.2	78.9	60.5	70.7	13.6	11.4	21.4	44.2	1.53	.0345	Do. " " "
44	9408	17.6	18.8	29.4	73.2	62.5	71.8	12.9	11.7	21.1	107.7	1.37	.0369	Do. " " "
48	9306	20.5	15.6	30.5	74.9	61.2	71.0	15.4	9.5	21.7	118.	1.26	.0266	V.N.P. " " "
51	11240	19.7	16.4	30.8	76.7	53.6	72.0	15.1	10.5	22.2	150	1.28	.0298	Do. " " "
54	14173	18.2	18.7	31.2	74.5	59.1	68.1	13.6	11.1	21.2	77.1	2.08	.0512	Do " " "
55	8347	21.2	17.5	30.5	74.6	52.6	71.5	15.8	9.2	21.8	112	0.92	.0210	Do " " "
56	13033	18.2	18.4	31.0	78.5	59.4	6.90	14.2	10.9	21.7	63.4	1.87	.0566	Do. " " "
57	14580	18.0	19.5	32.2	74.0	57.0	65.4	13.6	11.1	21.0	77.5	2.16	.0800	Do. " " "
58	6673	21.3	14.6	31.4	73.2	59.0	67.0	15.6	8.6	21.0	153	2.55	.0608	Do. " " "
59	10007	19.5	16.7	31.3	78.5	60.0	69.8	15.3	10.0	21.8	108	1.41	.0336	Do. " " "
60	11820	19.5	20.2	32.2	74.8	52.9	67.6	14.5	10.7	21.8	82.9	1.67	.0485	Do. " " "
61	11480	19.6	17.6	31.4	69.8	60.4	66.9	13.7	10.7	21.0	108	2.40	.0885	Do. Auxiliaries exhaust into Separator
62	15860	17.2	18.7	30.0	74.0	59.4	68.9	12.7	11.1	20.7	49.0	2.52	.0670	Do " " " Heaters.

TABLE 14 SERIES E AND F

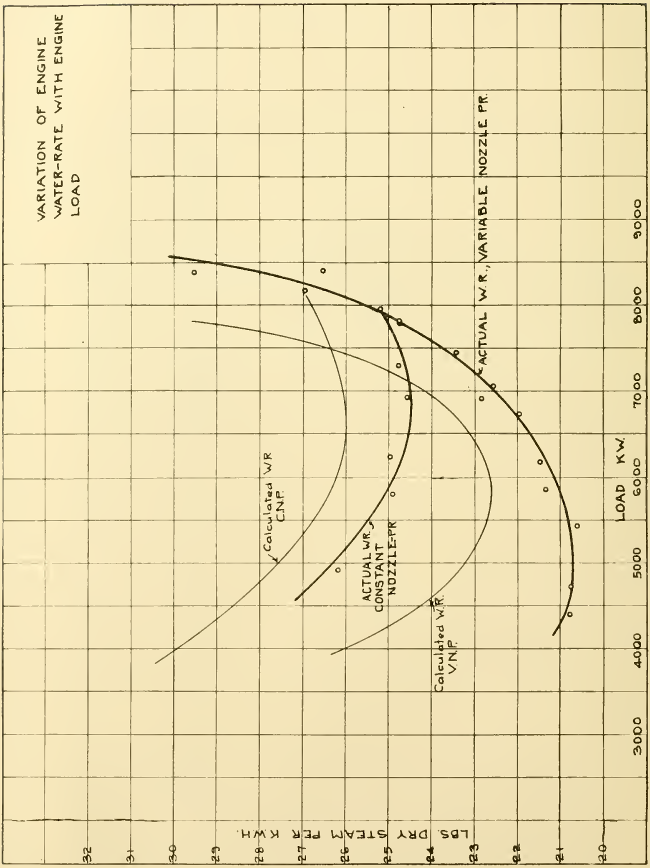


Fig. 13 Series E and F

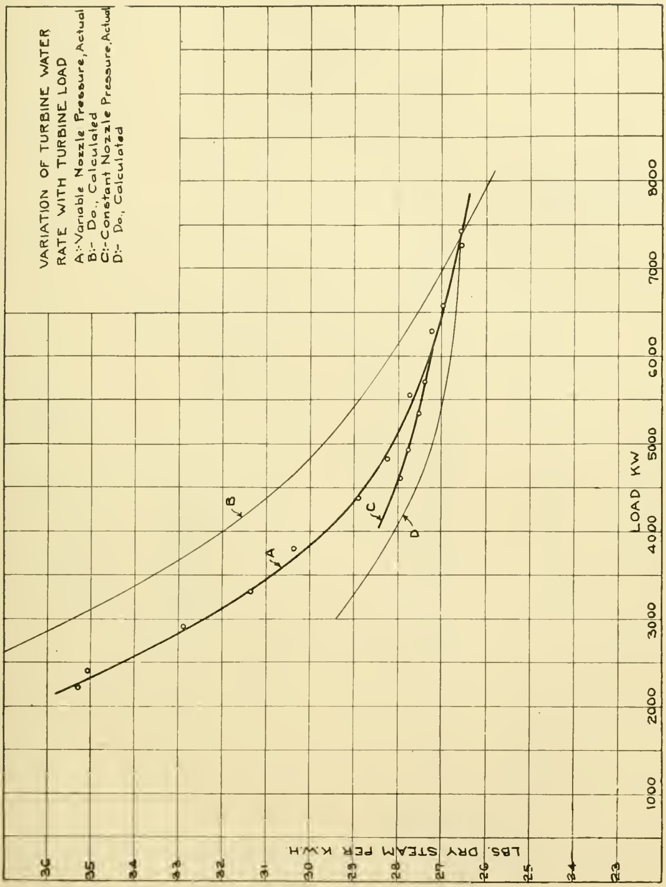


FIG. 14 SERIES E AND F

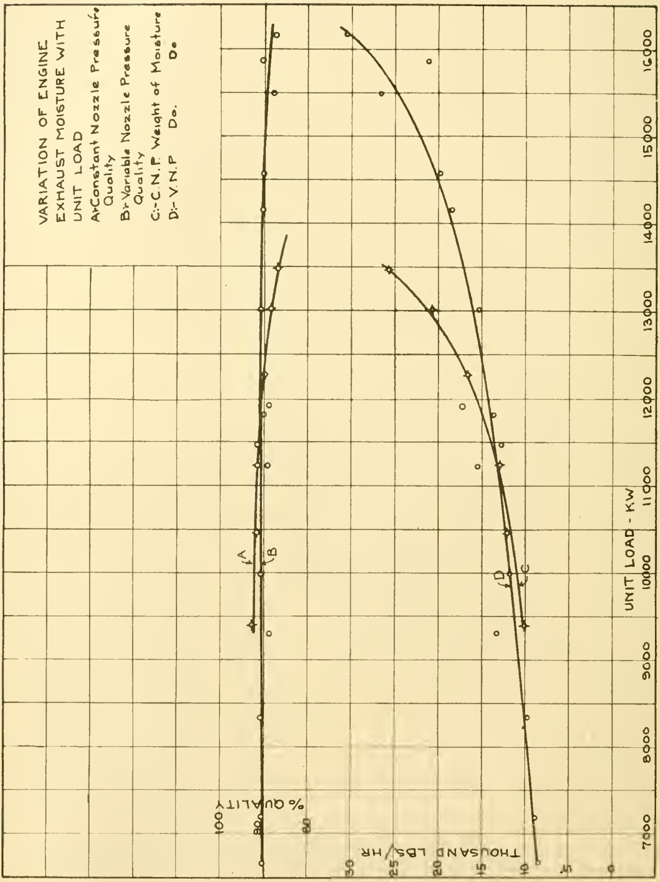


FIG. 15 SERIES E AND F.

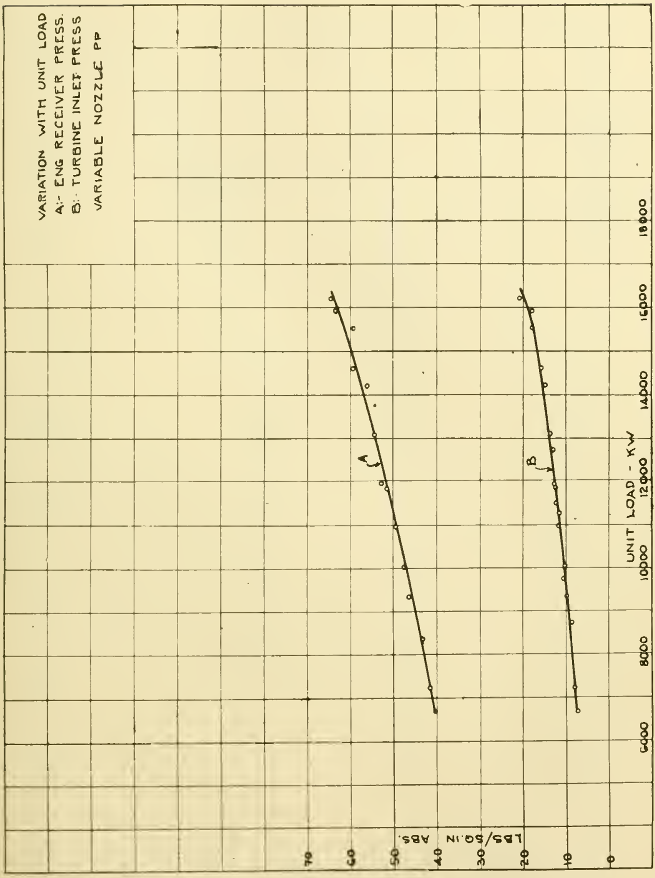


FIG. 16 SERIES E AND F

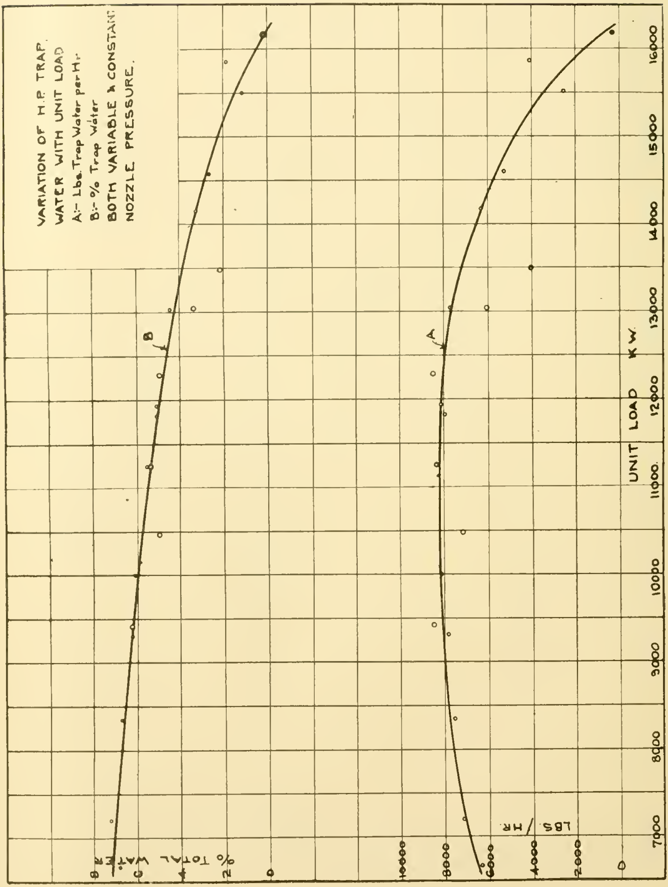


Fig. 17 Series E and F

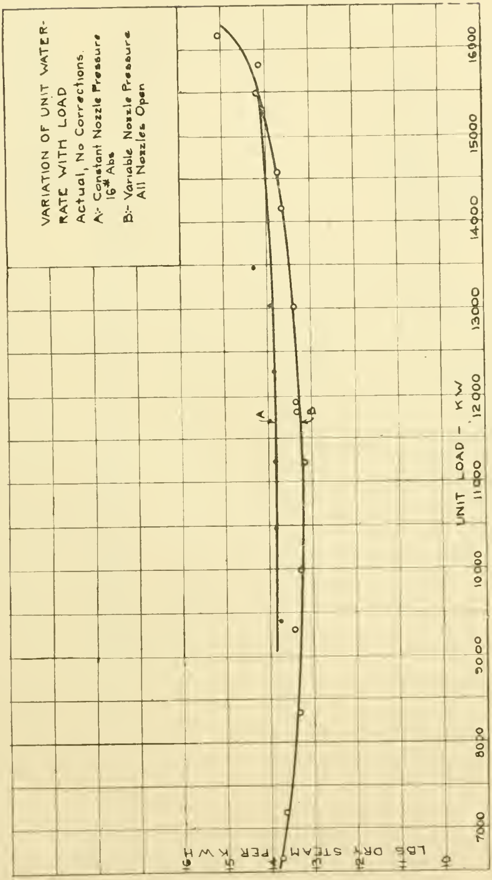


FIG. 18 SERIES E AND F

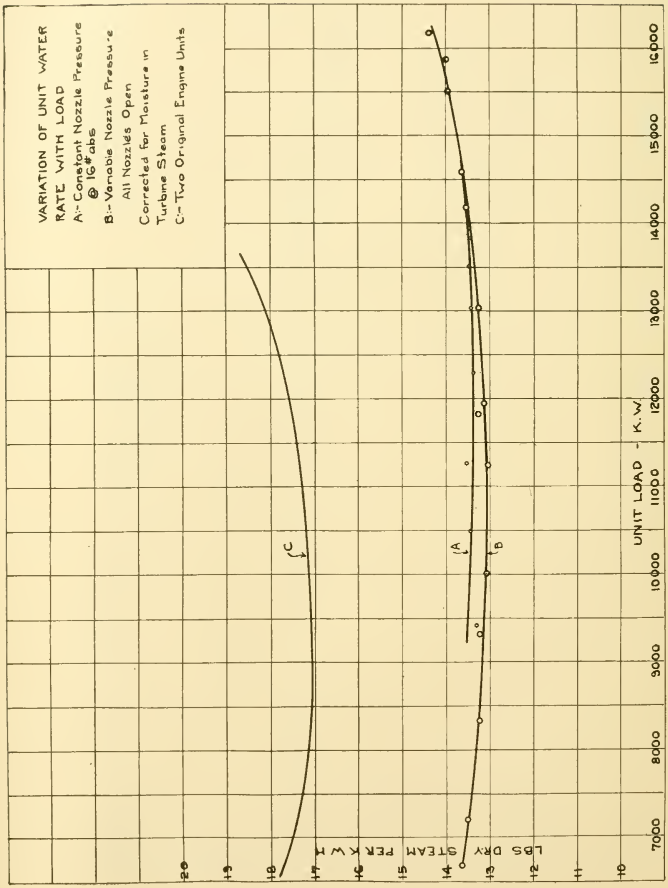


FIG. 19 SERIES E AND F

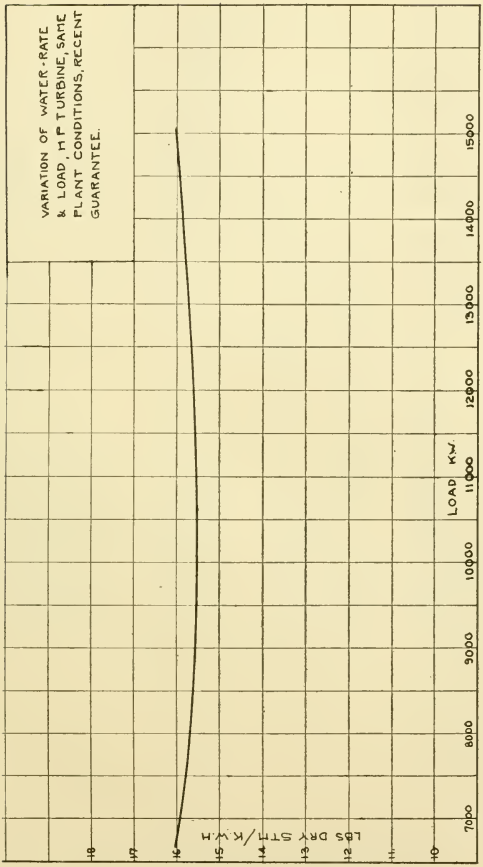


FIG. 19a SERIES E AND F

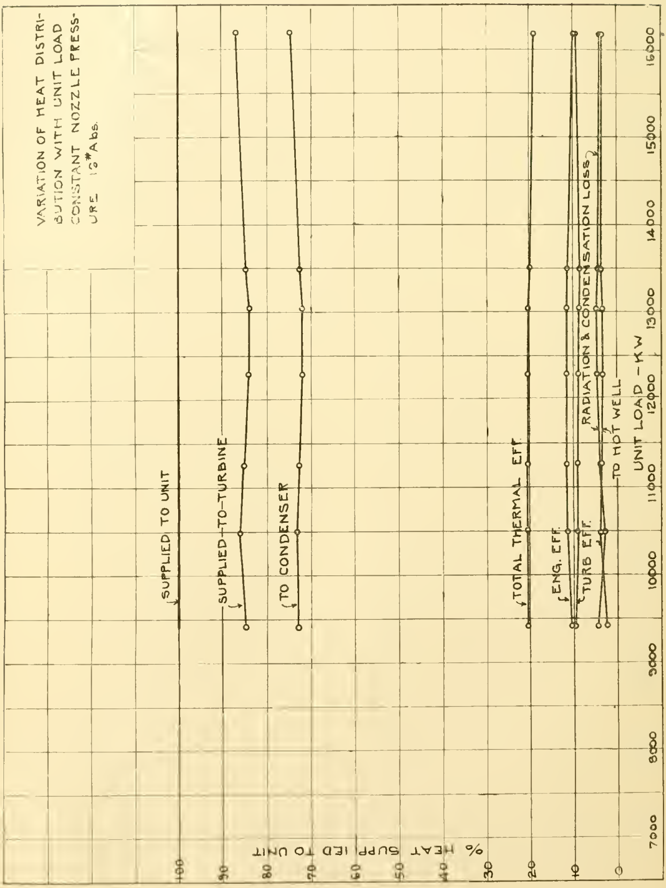


Fig. 20 Series E

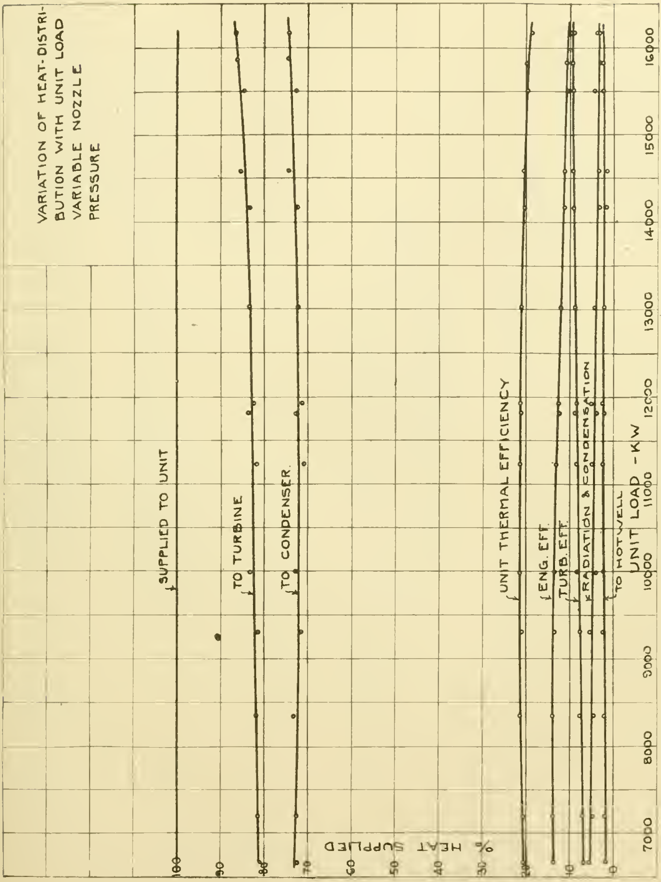


Fig. 21 Series F

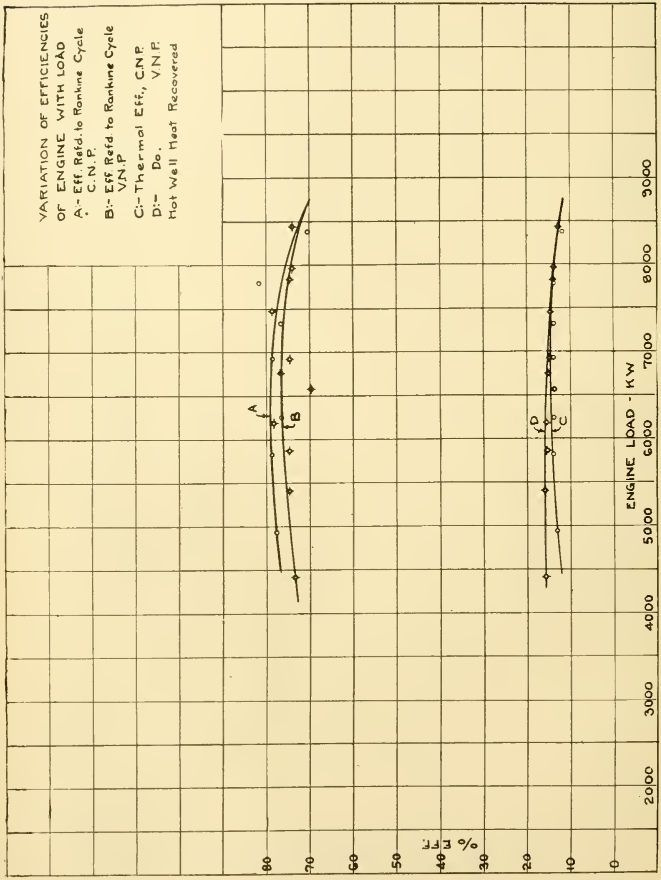


Fig. 22 Series E and F

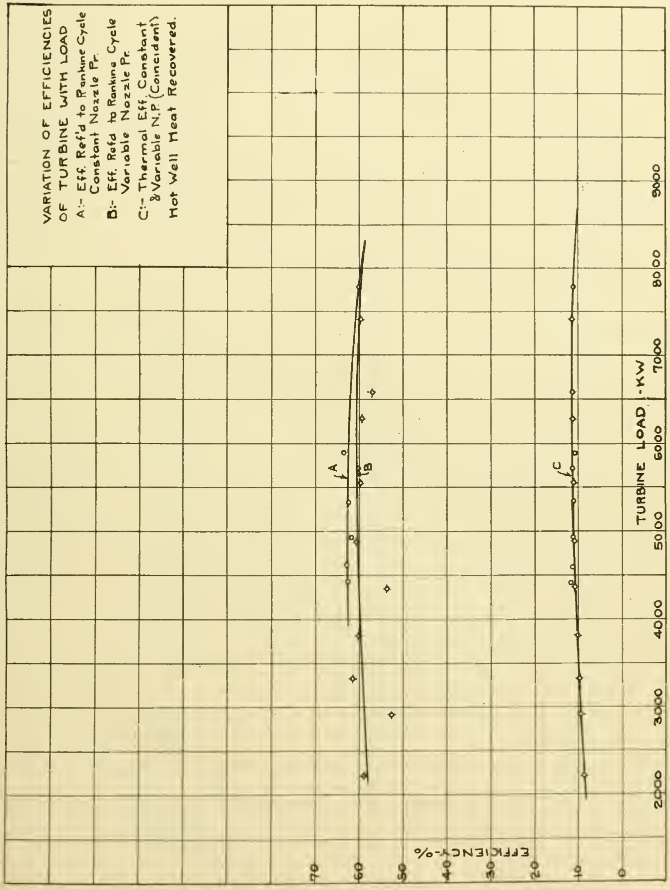


Fig. 23 Series E and F

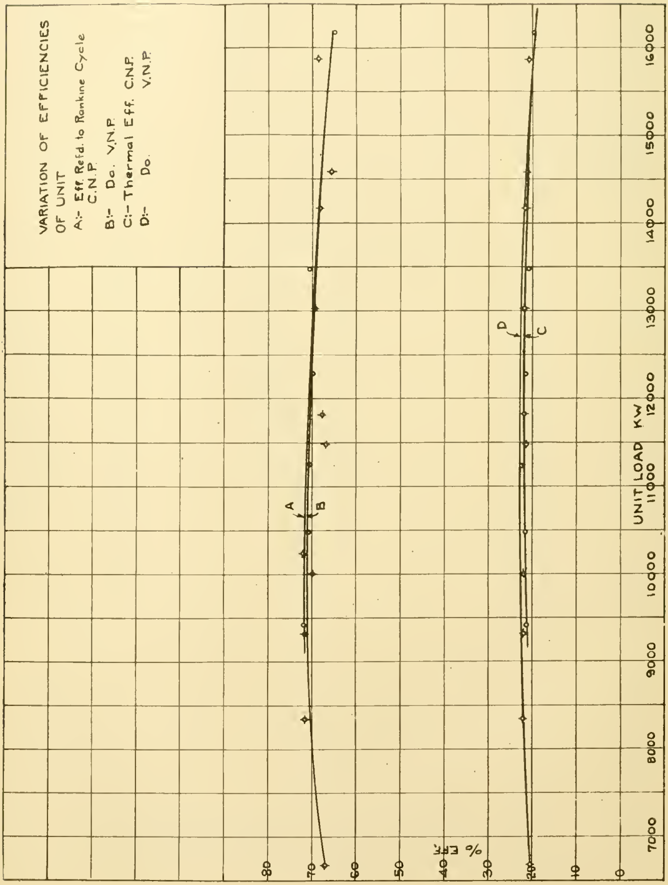


FIG. 24 SERIES E AND F

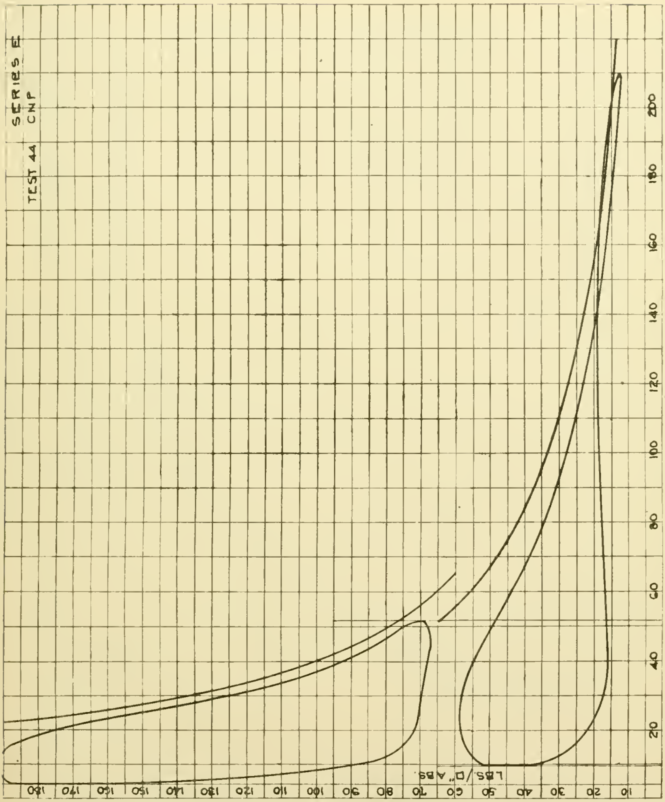


FIG. 25 SERIES E, TEST 44

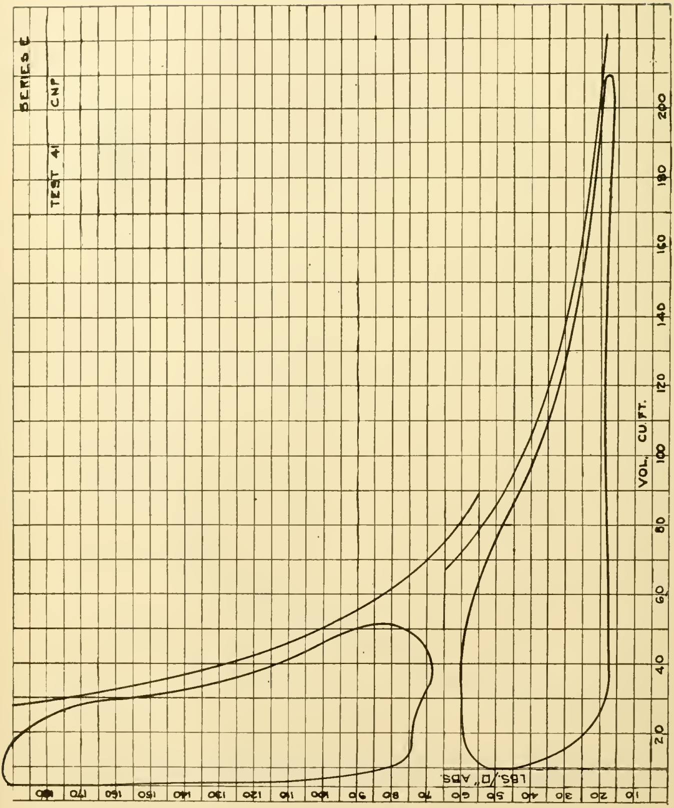


FIG. 26 SERIES E, TEST 41

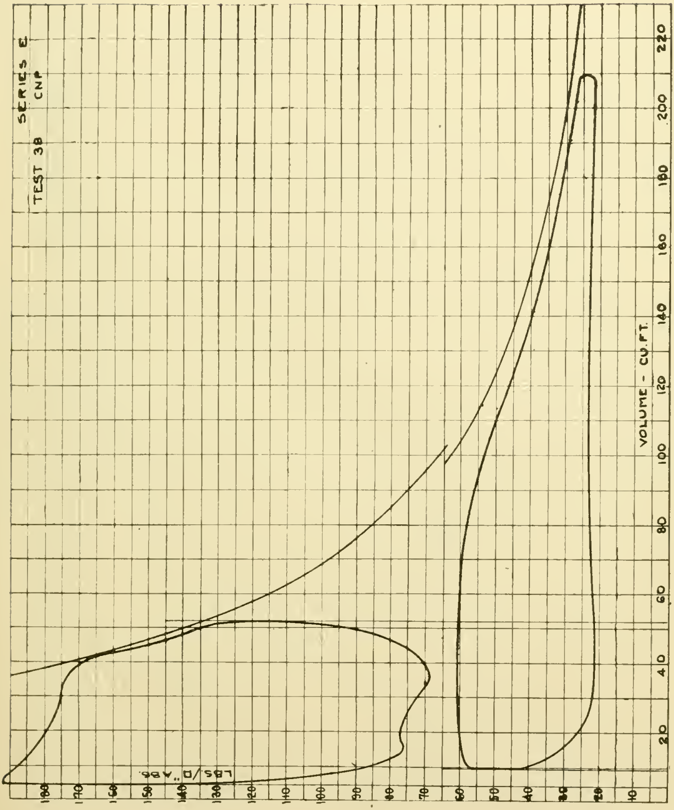


Fig. 27 Series E, Test 38

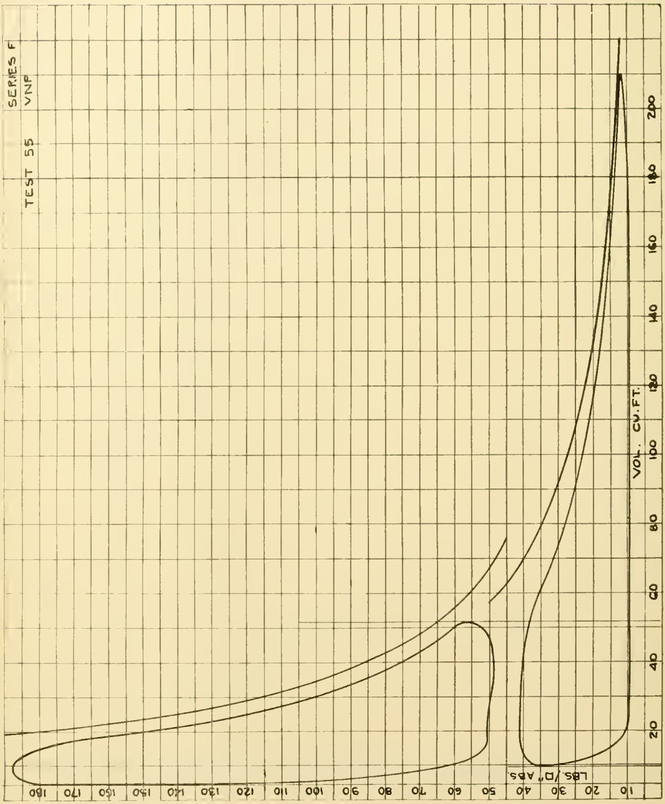


Fig. 28 Series F, Test 55

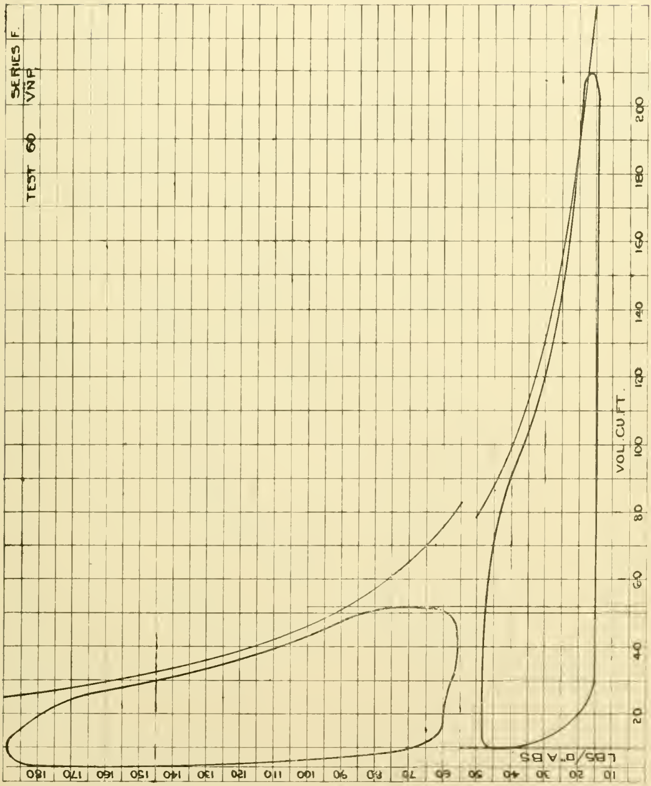


Fig. 29 Series F, Test 60

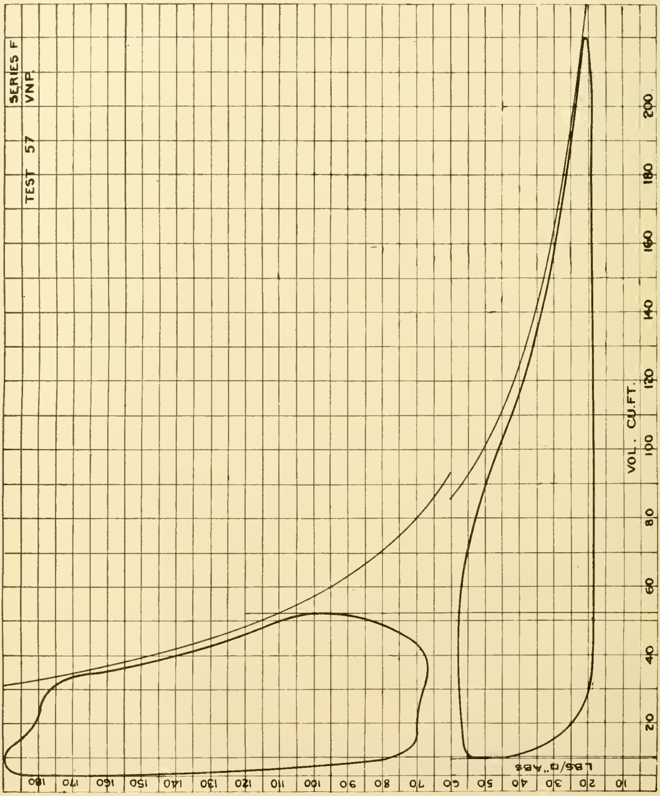


FIG. 30 SERIES F, TEST 57

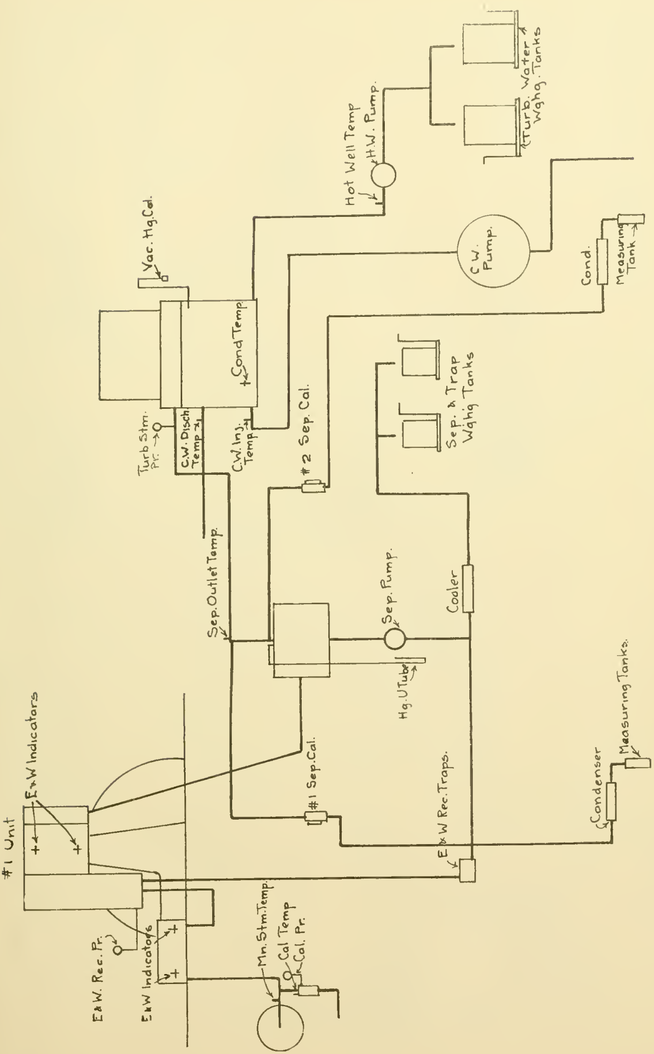


Fig. 31 Series C, Diagrammatic Test Layout

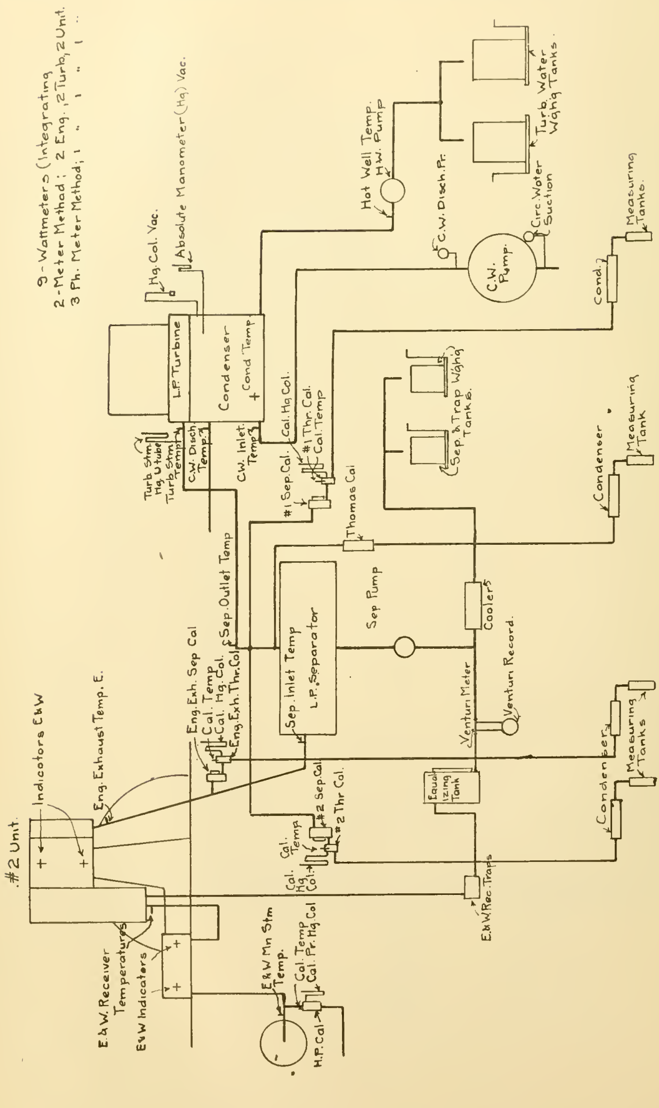


FIG. 32 SERIES D, E AND F, DIAGRAMMATIC TEST LAYOUT

ENGINE

2-H.P. CYL 42"×60", 9" rod
2-L.P. " 86"×60", 10" rod
R.P.M. 75.
2-14" STM. MAINS
2-16" H.P. EXH.
2-30" L.P. " .
Clearances
HP Head 9.5% Crank 10.0%
LP " 4.77 " 4.78
Avge. Total Volume H.P. 51.7 cu ft.
L.P. 209.9 " "

Avge. Displacement HP 47.0 " "
LP 200.3 " "

IHP Constant. HP 15.38 LP 65.57 (Avge)

All Combined Cards Worked out on Avge Basis.
Marks & Davis Tables Used for Steam Data

TABLE II.

E_r = Rankine Thermal Eff., cyclic
E_t = Engine " "
H_1 = Heat in initial steam @ press. p_1 quality x (Total per Hr)
H_2 = " " stm. @ p_2, x_2, after adiab. exp. from p_1, x_1 (Tot p. Hr)

$\frac{H_1 - H_2}{H_1} = E_r$ $E_t = \frac{KW \times 3412}{H_1}$ $\frac{E_t}{E_r} = E_e$ = Eng. Eff. Ref'd to Rankine Cycle

No Heat Recovered.

TABLE III

p_a, V_a = press. & vol. @ HP cutoff, lbs/□" & cu ft.
p_c, V_c = " " " @ HP compression
w_a = spec. density @ p_a
w_c = " " " p_c

$V_a w_a - V_c w_c = W$, lbs. indicated stm/stroke

$\frac{W \times 75 \times 4 \times 60}{\text{I.H.P.}}$ = Indicated Water Rate I.W.R.

$IWR(1+y) = AWR$, actual Water Rate

$y = .129(r - 4.06)$ K.W. × 1.465 = I.H.P.

$r = \frac{51.7}{V_a}$ for HP cyl. = Ratio of Expansion

TABLE IV

Q_e = Total Dry Stm. p. Hr. to Eng.
Q_f = Trap Water/Hr
X_e = L.P. Exhaust quality

$(Q_e - Q_f) X_e$ = Dry Stm to Turb., Q_t

TABLE VI & VII

X_t = Quality of Stm. to Turb. after passing Separator
$1 - X_t = w$, wetness do.
K_e = Eng. K.W. Output
K_t = Turb. " "

FIG. 33 FORMULAE AND CONSTANTS

TABLE VI & VII (Cont.)

Q_e = Dry Steam to Unit / Hr.

$\frac{Q_e}{K_e + K_t}$ = Actual Water Rate, $\overline{W}$ for Unit

Q_f = Trap Water/Hr.

Q_s = Separator Water/Hr

x_1 = HP Quality

$\frac{Q_e - Q_s - Q}{x_1} = Q_t'$

$Q_t' x_t = Q_t$

$\frac{Q_t}{K_t}$ = Actual Turb. Water Rate, $\overline{W}_t$

$\frac{Q_e}{K_e}$ = " Eng " " , $\overline{W}_e$

$\frac{Q_e}{K_e + K_t(1+w)}$ = Unit W.R., corrected for Moisture In Turb. Stm., $\overline{W}'$

$\overline{W}' - (28.5 - p_3') = \overline{W}''$ Total Corrected Unit W.R.

p_3' = Actual Vacuum Obtained, " Hg

TABLES IX & X

All Throttling Calorimeters

$x_1 = \frac{H_2 + K(T - t_2) - q}{L}$

H_2 = Tot. Heat/Lb. sat. stm @ p_2, cal. disch. pr.

x_1 = quality

K = Sp. Ht. Superheated stm. @ p_2, T

T = temp. Sup. stm. in Cal.

t_2 = " Sat. " @ p_2

q = Heat/Lb. of the liquid

L = Latent Ht. vaporization/Lb. @ p_1

All Separating Cals.

$x_2 = \frac{W_f}{W_m + W_f}$

W_m = Moisture

W_f = Flow

All Combination. Sep.—Throt. Cals.

$x_1 x_2 = x$, Combined Quality

Thomas Electric Cal.

$$\frac{\frac{3.412E}{W} - K(T - t)}{L} = 1 - x$$

E = Watt. Hrs. Input

W = Lbs. Stm Flow

K = as above

T = " "

t = sat. stm. temp @ p

L = Latent Ht/lb. @ p

x = as above

TABLE XII, see VI, VII

TABLES XIII, XIV

$E_t = \frac{K.W. 3412}{H_1}$ for Eng. Turb. or Unit.

$E_t' = \frac{K.W. 3412}{H_1 - q}$ for Unit & Turbine Only

E_t = Therm. Eff. No Heat Recovered

E_t' = " " Hot Well Heat "

FIG. 33a FORMULAE AND CONSTANTS

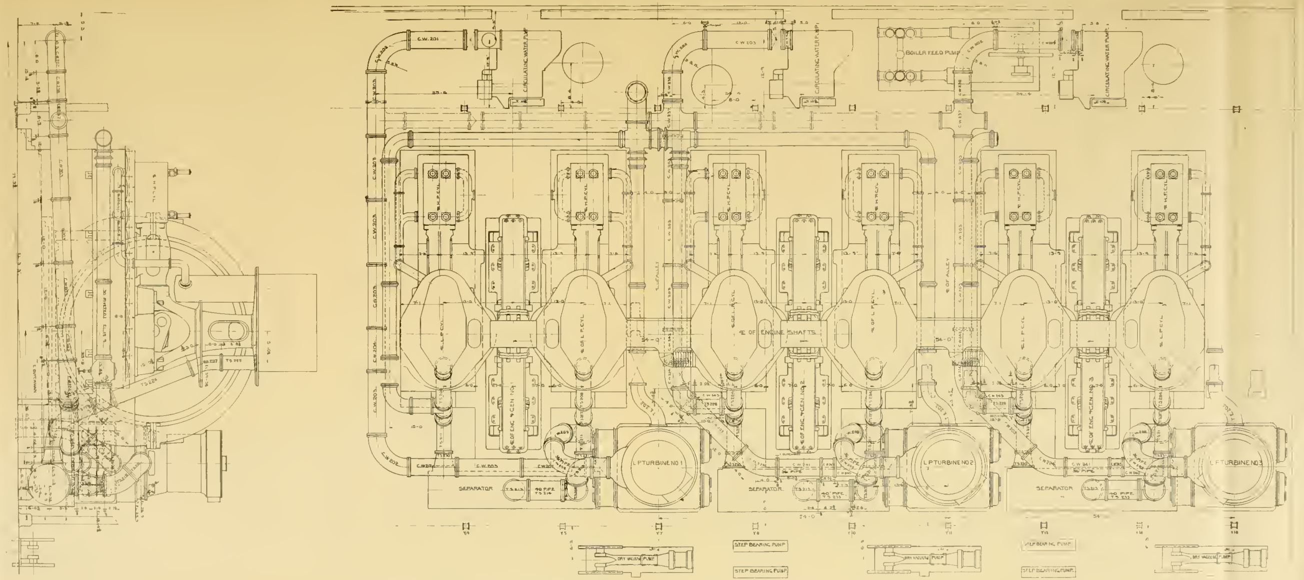


PLATE 1 END ELEVATION AND PLAN OF ENGINE AND LOW-PRESSURE TURBINE UNITS; 59TH STREET STATION, INTERBOROUGH RAPID TRANSIT COMPANY

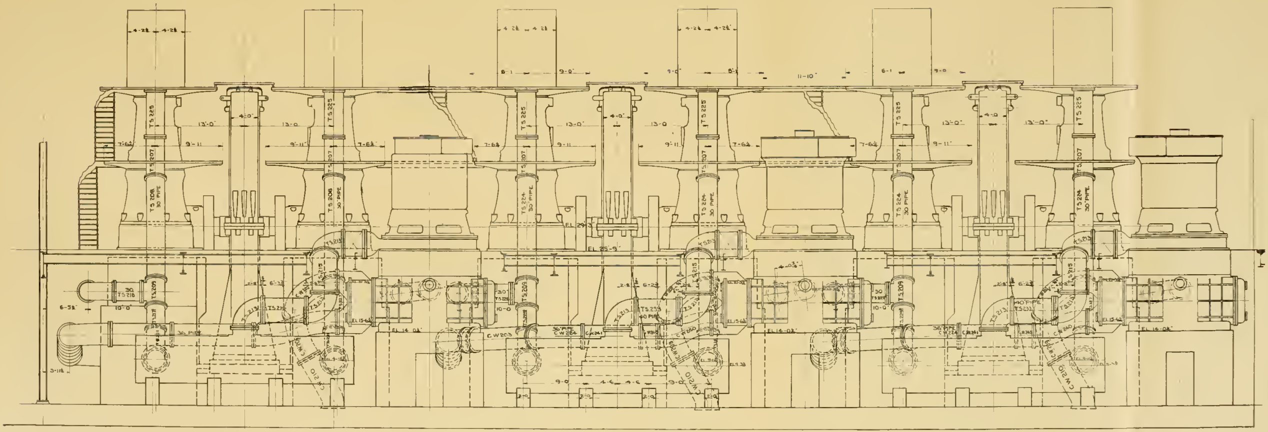


PLATE 2 SIDE ELEVATION OF ENGINE AND LOW-PRESSURE TURBINE UNITS; 59TH STREET STATION, INTERBOROUGH RAPID TRANSIT COMPANY

THE ELASTIC LIMIT OF MANGANESE AND OTHER BRONZES

By J. A. Capp, Schenectady, N. Y.

Member of the Society

To keep up with the demands upon the laboratory for more work in a given time, testing machines have been speeded up and the slow extensometer has largely been displaced by the dividers, used either unchanged or with some means of magnification. To represent castings and forgings the short test piece with one-half inch diameter and two-inch gage length is almost universal. As a consequence, while reports of tests usually include a statement of "elastic limit," the property of the material actually determined is in reality that more or less vague value called the yield point. It is the object of this paper to show that while the yield point for steel is so well marked in properly conducted tests, and bears a sufficiently definite relation to the true elastic limit to warrant the dependence placed upon it by the engineer, there is no equally well defined point found in testing bronzes, and the value commonly obtained from rapid commercial tests as the elastic limit or yield point on bronze may be quite misleading.

2 Manganese bronze was selected as the metal to be subjected to the series of tests here recorded because, of the modern alloys, it is one of the strongest and is readily obtainable in the market. It is not proposed, however, to discuss at length the properties of manganese bronze as such. This metal is used as a type and the results, so far as behavior under a tensile test is concerned, may be taken as typical of brasses and bronzes in general, at least so far as they have come under the observation of the author in some seventeen years of testing materials.

3 Specifications issued by the Navy Department for managanese

The American Society of Mechanical Engineers, 29 W. 39th St., N. Y.
All papers are subject to revision.

bronze, March 30, 1909, required the following approximate composition:

Copper	52 per cent
Iron	1 per cent
Zinc	46 per cent
Tin	1 per cent
Manganese	Trace
Aluminum	0.5 per cent

The specification further required:

Tensile Strength	65,000 lb. per sq. in.
Elastic Limit	30,000 lb. per sq. in.
Elongation	15 per cent in 2 in.
Reduction of area	25 per cent

They state "the elastic limit is to be the yield point, measured by the drop of the bar."

4 Manganese bronze castings in the form of cylindrical bars about 1½ in. in diameter by 24 in. long, were ordered from several foundries supplying this alloy; the orders were placed through the regular channels, bars of about this size being required in ordinary production. In this way it was hoped that commercial material would be obtained, such as might be expected in castings of more intricate shape. The results on these specimens, ordered without reference to intended use, checked very well with those upon samples submitted previously by the same parties, especially for the purpose of showing the qualities of their material. To indicate the effect of working upon the metal, there were also ordered two bars of the same dimensions hot-rolled to size, and two bars hot-rolled and cold-drawn. The effect of the cold drawing was lost to a great extent by the necessary turning off of the surface in preparing the specimen for test. Much of the cold-drawn metal is used in this way, however, when screw threads are required to provide means of fastening the part in place in the structure. From the bars so obtained, specimens were turned which provided a test section 1 in. in diameter by 8 in. between gage marks, and which had, for the purpose of gripping, ends 1½ in. in diameter threaded to fit the nuts required by the testing machine.

5 Some of these specimens were pulled in the laboratory of the General Electric Company at Schenectady, some in the testing machine at the United States Arsenal at Watertown, and others in the laboratory of the Halcomb Steel Company at Syracuse. The tests

in the Halcomb laboratory were made to obtain autographic strain diagrams; the other tests were made with an extensometer.

6 In the tests with the extensometer, after the instrument had been placed, an initial load of 1000 or 2000 lb. per sq. in. was applied and the first reading taken; readings were than obtained at successive

TABLE 1 CAST MANGANESE BRONZE, MARK 9902 B

Extensometer Test

Original Diameter, 0.9995 in. Original length, 8 in.

Stress		Extensometer Readings		Mean Difference	Strain	
					Total	Unit
Actual	Per Sq. In.	Right	Left	Initial Reading		
1,570	2,000	0.0235	0.0075			
3,140	4,000	0.0245	0.0089	0.00120	0.0012	0.00015
4,710	6,000	0.0254	0.0107	0.00135	0.00255	0.00032
6,275	8,000	0.0263	0.0122	0.00120	0.00375	0.00047
7,845	10,000	0.0272	0.0136	0.00115	0.00490	0.00061
9,415	12,000	0.0282	0.0151	0.00125	0.00615	0.00077
10,985	14,000	0.0293	0.0165	0.00125	0.00740	0.00092
12,555	16,000	0.0306	0.0181	0.00145	0.00885	0.00111
14,120	18,000	0.0320	0.0198	0.00155	0.01040	0.00130
15,690	20,000	0.0342	0.0219	0.00215	0.01255	0.00157
17,260	22,000	0.0370	0.0246	0.00275	0.01530	0.00191
18,830	24,000	0.0414	0.0279	0.00385	0.01915	0.00239
20,400	26,000	0.0456	0.0321	0.00420	0.02335	0.00292
53,040	67,600	Tensile Strength				

Reduced diameter............ 0.695 in.
Reduction of area.............51.6 per cent
Length after test..............10.20 in.

Elongation................... .27.5 per cent
Elastic limit (from curve) 15,000 lb. per sq. in.
Modulus of elasticity 12,900,000 lb. per sq. in.

Commercial Test

Original diameter............. 0.503 in.
Original length................ 2 in.
Reduced diameter .... 0.387 in.
Length after test.............. 2.65 in.

Reduction of area...........40.8 per cent
Elongation...................32.5 per cent
Rapid stretch (yield point).26,000 lb. per sq. in.
Tensile strength.............69,650 lb. per sq. in.

loads applied in equal steps. In some cases, the readings were continued regularly until the increase in extension per increment of load was so great that there was no doubt that the strain diagram had departed markedly from the straight line demanded by Hook's law; in other tests, the normal succession of readings was continued only

TABLE 2 CAST MANGANESE BRONZE, MARK 9902-A

Extensometer test

Original diameter 0.995″.
Original length 8.″.

Stress		Extensometer Readings		Mean Difference	Strain	
Actual	Per Sq. In.	Right	Left		Total	Unit
1,570	2,000	0.0255	0.0125		Initial Reading	
3,140	4,000	0.0270	0.0133	0.00115	0.00115	0.00014
4,710	6,000	0.0282	0.0147	0.00130	0.00245	0.00031
6,275	8,000	0.0290	0.0163	0.00120	0.00365	0.00046
7,848	10,000	0.0298	0.0179	0.00120	0.00485	0.00061
9,415	12,000	0.0307	0.0194	0.00120	0.00605	0.00076
10,985	14,000	0.0318	0.0208	0.00125	0.00730	0.00091
12,555	16,000	0.0328	0.0223	0.00125	0.00855	0.00107
14,120	18,000	0.0342	0.0239	0.00150	0.01005	0.00126
1,570	2,000	0.0264	0.0122	0.0003	set	....
14,120	18,000	0.0345	0.0232	....	....	....
15,690	20,000	0.0360	0.0253	0.00180	0.01185	0.00148
1,570	2,000	0.0270	0.0125	0.00075	set	
15,690	20,000	0.0365	0.0250	....	....	....
17,260	2,2000	0.0384	0.0273	0.00210	0.01395	0.00174
18,830	24,000	0.0412	0.0301	0.00280	0.01675	0.00209
1,570	2,000	0.0291	0.0140	0.00265	set	....
18,830	24,000	0.0418	0.0296	....	....	....
20,400	26,000	0.0446	0.0332	0.00320	0.01995	0.00249
53,480	68,160	Tensile Strength				

Reduced diameter..0.717 in.
Reduction of area..48.5 per cent
Length after test..10.22 in.
Elongation..27.8 per cent
Elastic limit (from curve)............................16,000 lb. per sq. in.
Modulus of elasticity............................13,000,000 lb. per sq. in.

Commercial Test

Original diameter..0.5028 in.
Original length..2 in.
Reduced diameter..0.338 in.
Length after test..2.84 in.
Reduction of area..54.8 per cent.
Elongation..42.0 per cent
Rapid stretch (yield point)............................25,000 lb. per sq. in.
Tensile strength..67,940 lb. per sq. in.

until the first positive increase in extension per increment of load was noted, when the stress was reduced to the initial load for the measurement of permanent set, after which the load was returned to the value just left, a new reading taken and the test continued with further determinations of set intervals. The values of stress and corresponding strain obtained were plotted, and the elastic limit recorded as the stress at the point of inflexion of the curve drawn through the points.

7 The specimens subjected to these tests were about 12 in. long over all. From the remainder of the 24-in. bars, the usual ½ in. by 2 in. test pieces were turned and tested in the customary commercial way, using a pair of multiplying dividers to indicate the point of increase in rate of stretch or yield point.

TABLE 3 EXTENSOMETER AND COMMERCIAL TESTS

Extensometer Tests: All Specimens 1 in. (Approximate) Dia. by 8 In. Long.

Mark	9908B	Q2992A	Q2992B	Q6434A
Sample	Cast	Hot-Rolled	Hot-Rolled	Cold-Drawn
Reduction of area, per cent	14.1	52.2	52.2	53.3
Elongation, per cent	6.25	33.5	33.75	31.0
Elastic limit, lb. per sq. in	19,400	18,000	18,000	17,000
Tensile strength, lb. per sq. in	62,070	71,800	71,640	71,620
Modulus of elasticity, lb. per sq. in	13,810,000	13,000,000	13,810,000	12,800,000

Commercial Tests: All Specimens 0.5 in. (Approximate) Dia. by 2 In. Long.

Sample	Cast	Hot-Rolled	Hot-Rolled	Cold-Drawn
Reduction of area, per cent	28.5	44.9	45.9	39.9
Elongation, per cent	26.5	37.5	36.5	34.0
Yield Point (rapid stretch), lbs. per sq. in.	29,000	30,000	30,000	43,000
Tensile strength, lbs. per sq. in	80,420	74,780	74,480	74,260

Bar 9908B was unsound, hence ½ in. by 2 in. test was turned from side of bar, instead of center. Unsoundness due to oxidation and perhaps segregation, probably accounts for the apparent cold shortness of the 1 in. by 8 in. test piece. Fracture occurred in a flaw, while many incipient fractures or cracks were noted in surface before final rupture.

8 In Table 1 are given in detail a typical set of readings taken in a test at regularly increasing loads, together with the results of the commercial test upon the specimen from the same bar. In Table 2, similar data are given from a test with measurements of set. Table 3 shows the results obtained upon the other specimens tested at Schenectady. The curves for all these tests are assembled on Fig. 1. Details of the tests at the Watertown Arsenal are stated in Tables 4

and 5, and the curves from these data are given on Fig. 2. The results of the work at the Halcomb laboratory are shown in Table 6 and Fig. 3; the scale of the diagram is so small that the location of the point of inflexion is uncertain within about 2000 lb. actual load, and the values in the tables are placed rather high. The multiplying dividers used in the commercial tests here recorded magnify the movement of the gage marks about ten times, and are a much more sensitive instrument than the machinists' dividers for locating the yield point; hence, the yield points recorded are lower than are usually reported.

9 In the text books and elsewhere, the limit of elasticity is defined

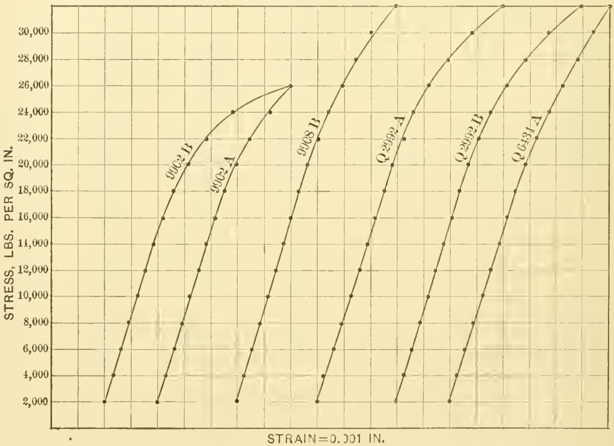


Fig. 1 Curves Plotted from Data in Tables 1, 2 and 3

as that value of stress beyond which there is not full recovery of the initial dimensions or shape of the specimen after release of the load, or as the maximum stress that can be applied without producing permanent set. In other words, it is the value of stress beyond which Hook's law no longer holds, and it is sometimes spoken of as the limit of proportionality of stress to strain.

10 Accepting this definition of elastic limit, it is seen that its value in the bronzes tested is from 16,000 lb. per sq. in. to 23,000 lb. per sq. in., whereas the yield points found for the cast metals ran from 25,000 lb. to 29,000 lb., and for the worked metals, from 30,000

TABLE 4 CAST MANGANESE BRONZE, MARK 9902 B

WATERTOWN ARSENAL TEST

Original Diameter, 1.000 in. Original length, 8 in.

Stress		Reading	Difference	Strain		Set
Actual	Per Sq. In.			Total	Unit	
785	1,000			Initial Reading		
1,571	2,000	0.0008	0.0008	0.0008	0.00010	....
2,356	3,000	0.0013	0.0005	0.0013	0.00016	....
3,142	4,000	0.0020	0.0007	0.0020	0.00025	....
3,927	5,000	0.0027	0.0007	0.0027	0.00034	0
4,712	6,000	0.0033	0.0006	0.0033	0.00041	....
5,498	7,000	0.0038	0.0005	0.0038	0.00048	....
6,283	8,000	0.0044	0.0006	0.0044	0.00055	....
7,069	9,000	0.0051	0.0007	0.0051	0.00064	....
7,854	10,000	0.0060	0.0009	0.0060	0.00075	0
8,639	11.000	0.0067	0.0007	0.0067	0.00084	....
9,425	12,000	0.0075	0.0008	0.0075	0.00094	....
10,210	13,000	0.0080	0.0005	0.0080	0.00100	....
10,996	14,000	0.0086	0.0006	0.0086	0.00108	....
11,781	15,000	0.0090	0 0004	0.0090	0.00113	0
12,566	16,000	0.0105	0.0015	0.0105	0.00131	....
13,352	17,000	0.0119	0.0014	0.0119	0.00149	0.0005
14,137	18,000	0.0133	0.0014	0.0133	0.00166	....
14,923	19,000	0.0145	0.0012	0.0145	0.00181	....
15,708	20,000	0.0167	0.0022	0.0167	0.00209	0.0025
19,635	25,000	0.0280	0.0113	0 0280	0.00350	0.0085
23,562	30,000	0.0487	0.0207	0.0487	0.00609	0.0241
31,416	40,000	0.2090	0.1603	0.2090	0.02613	0.1730
50,600	64,458	Tensile Strength				

Reduced diameter... 0.70 in.
Length after test ....10.53 in.
Reduction of area..51.0 per cent.
Elongation..31.6 per cent.
Elastic limit..16000 lb. per sq. in.
Modulus of elasticity, 12,390,000 lb. per sq. in.

COMMERCIAL TEST (MADE AT SCHENECTADY)

Original diameter..0.503 in.
Original Length..2 in.
Reduced diameter..0.387 in.
Length after test..2.65 in.
Reduction of area..40.8 per cent.
Elongation..32.5 per cent.
Rapid stretch (yield point) ....26000 lb. per sq. in.
Tensile strength..69650 lb. per sq. in.

TABLE 5 CAST MANGANESE BRONZE, MARK 9908B

WATERTOWN ARSENAL TESTS

Original diameter, 0.7854 in. Original length, 8 in.

Stress		Reading	Difference	Strain		Set
Actual	Per Sq. In.			Total	Unit	
785	1000	0		Initial Reading		
1571	2000	0.0007	0.0007	0.0007	0.00009	....
2356	3000	0.0013	0.0006	0 0013	0.00016	....
3142	4000	0.0017	0.0004	0.0017	0.00021	....
3927	5000	0.0023	0.0006	0.0023	0.00029	0
4712	6000	0.0028	0.0005	0.0028	0.00035	....
5498	7000	0.0036	0.0008	0.0036	0.00045	....
6283	8000	0.0040	0.0004	0.0040	0.00050	....
7069	9000	0.0047	0.0007	0.0047	0.00059	....
7854	10000	0.0052	0.0005	0.0052	0.00065	0
8639	11000	0.0059	0.0007	0.0059	0.00074	....
9425	12000	0.0064	0.0005	0.0064	0.00080	....
10210	13000	0.0070	0.0006	0.0070	0.00088	....
10996	14000	0.0074	0.0004	0.0074	0.00093	....
11781	15000	0.0081	0.0007	0.0081	0.00101	0
12566	16000	0.0088	0.0007	0.0088	0.00110	....
13352	17000	0.0094	0.0006	0.0094	0.00118	....
14137	18000	0.0099	0.0005	0.0099	0.00124	....
14923	19000	0.0104	0.0005	0.0104	0.00130	....
15708	20000	0.0113	0.0009	0.0113	0.00141	0.0001
16493	21000	0.0120	0.0007	0.0120	0.00150	....
17279	22000	0.0126	0.0006	0.0126	0.00158	....
18064	23000	0.0135	0.0009	0.0135	0.00169	0.0003
18850	24000	0.0143	0.0008	0.0143	0.00179	....
19635	25000	0.0156	0.0013	0.0156	0.00195	0.0010
20420	26000	0.0165	0.0009	0.0165	0.00206	....
21206	27000	0.0171	0.0006	0.0171	0.00214	0.0015
21991	28000	0.0185	0.0014	0.0185	0.00231	....
22777	29000	0.0200	0.0015	0.0200	0.00250	....
23562	30000	0.0210	0.0010	0.0210	0.00263	0.0034
27489	35000	0.0325	0.0115	0.0325	0.00406	0.0118
31416	40000	0.0607	0.0282	0.0607	0.00759	0.0384
35343	45000	0.1225	0.0618	0.1225	0.01531	0.0920
53900	68662	Tensile Strength				

Reduced diameter........... 0.91 in.
Length after test............ 8.85 in.
Reduction of area.......... 17.2 per cent.

Elongation.................. 10.6 per cent.
Elastic limit................ 23000 lb. per sq. in.
Modulus of elasticity, 13,300,000 lb. per sq. in.

COMMERCIAL TEST (MADE AT SCHENECTADY)

Original diameter......... 0.504 in.
Original length............ 2 in.
Reduced diameter......... 0.426 in.

Length after test.......... 2.53 in.
Elongation................ 26.5 per cent.
Rapid stretch (yield point) 29,000 lb. per sq. in.

Tensile strength........... 80,420 lb. per sq. in.

lb. to 44,000 lb. per sq. in. Had ordinary dividers been used, the values for the cast metals would have been placed between 30,000 lb. and 40,000 lb. per sq. in. The strain diagrams from the extensometer tests show the general shape of the elastic curve of the metal, and permit the accurate fixing of the point of inflexion of the curve; the autographic diagrams, however, show not only the actual shape of the curve, but also why there is the uncertainity in the locating of the yield point or point of rapid increase in rate of stretching.

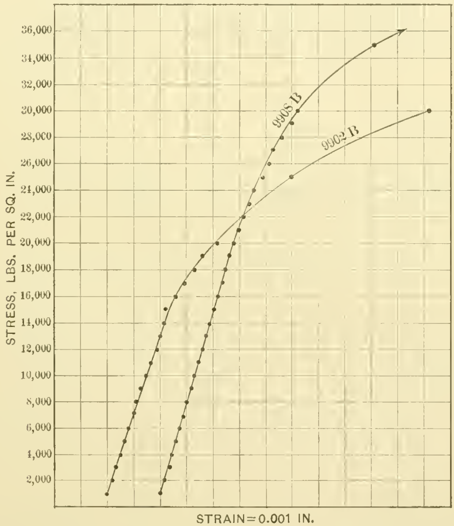


Fig. 2 Curves Plotted from Data in Tables 4 and 5

11 For comparison, the autographic diagram of a piece of commercial "structural medium" steel is shown as No. 1 in Fig. 3. At the scale of the diagram, no inflexion of the curve is seen until it suddenly breaks sharply, actually drops and remains practically horizontal until it finally picks up again. This jog is entirely characteristic of mild steel, and is found to a more or less marked extent in all steels, save perhaps the very hard varieties. There is, however, no break of any sort in the curves obtained from bronze; they are entirely smooth. Somewhere along the knee of the curve, the tester

notes that the material is stretching faster; just where he notices it will depend upon the sensitiveness of the means employed to indicate stretch, and upon his skill and sharpness in observation. The jog in the steel curve is indicated simultaneously by the slipping of the dividers and by the dropping of the scale beam of the testing machine driven at constant speed. The scale beam does not drop when testing bronze; the operator finds the poise gradually traveling more

TABLE 6 HALCOMB STEEL COMPANY TESTS

Autographic Tests All Specimens 1-In. (Approximate) Dia. by 8-In. Long.

Mark		9902A	9908A	Q2992A	Q6434A
Number on Curve Sheet	1	2	3	4	5
Sample	Steel	Cast	Cast	Hot-Rolled	Cold-Drawn
Reduction of area, per cent	53.6	8.3	14.1	53.2	38.6
Elongation, per cent	36.3	27.2	6.6	34.4	25.2
Elastic limit, lbs. per sq. in	38,000	21,400	22,900	22,800	25,200
Tensile strength, lbs. per sq. in	60,140	69,700	63,940	71,820	68,500

Commercial Tests (Made at Schenectady): All Specimens 0.5 in. Dia. by 2 in. Long.

Sample	Cast	Cast	Hot-Rolled	Cold-Drawn
Reduction of area, per cent	54.8	22.4	44.9	39.9
Elongation, per cent	42.0	14.5	37.5	34.0
Yield point, lbs. per sq. in	25,000	26,000	30,000	44,000
Tensile strength, lbs. per sq. in	67,940	70,900	74,780	74,260

slowly to maintain balance, but who can say when the change in rate began?

12 It is customary to find the yield point in mild steels, and in fact, in annealed steels generally, at about 50 per cent of the maximum strength. The yield point in mild steels corresponds, for all practical purposes, with the elastic limit. As the steel becomes harder, due to increase in carbon or the addition of alloying metals, or to heat treatment, the yield point rises rather more rapidly than the elastic limit, although the difference between the two is not so great but that the former may be used in calculations, and the yield point itself is less sharply marked, though still observable if sufficient care is taken. The yield point in steel is accepted as a safe guide to the engineer, in deciding upon the maximum stresses that may safely be permitted in parts designed to carry load.

13 That no such dependence can be placed upon the so-called yield point, as it is determined upon bronzes, is evident; rather, recourse must be had to the slower but more accurate determination of the true elastic limit if safe data are desired. It is especially noteworthy that the sets found at the minimum values of yield point as usually reported are a very considerable proportion of the total stretch that has taken place in the metal at those stresses, and that sets are found at stresses which are but 40 to 50 per cent of these reported yield points. Under certain conditions of dead load, a stress of 75 per cent of the elastic limit is sometimes considered at least not unsafe; if such a load were calculated for bronze, upon the basis of the usual commercial test for yield point, instability of the part so designed would be inevitable.

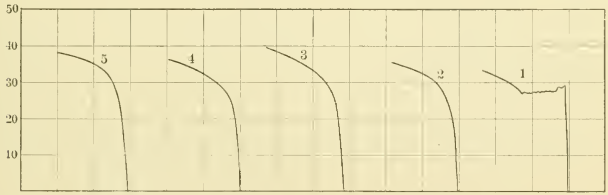


Fig. 3 Autographic Strain Diagrams to Accompany Data in Table 6

14 Hot working of the metal has not materially improved its elastic properties, but has greatly increased its toughness, and probably in an extended series of tests, would have been found to impart uniformity. It is well known that this particular alloy is relatively difficult to handle in the foundry because of its sensitiveness to temperature of pouring and to changes in composition, at least in the sense of impurities in the constituent metals, and because of its great shrinkage, requiring large feeders and sink heads. As in other copper alloys, many of the ill effects of this sensitiveness may be largely overcome by hot working. The data here presented are too meager to warrant lengthy discussion of the effects of cold working of the metal; it is shown that in the case of bars of $1\frac{1}{2}$ in. diameter, the effects of the cold drawing may have largely disappeared when $\frac{1}{4}$ in of metal is removed, except as shown in a lessened elongation. Neither hot or cold working cause any change in the elastic curve of the metal; it remains a characteristically smooth curve. In other cold-drawn copper alloys, when tested without removal of surface, the elastic curve

usually presents a much sharper bend at the knee than is found in the cast metal, or in the same metal when annealed; the same would probably be found with manganese bronze if tested as drawn, without turning. Cold-drawn metal, except wire, is seldom used without removal of the surface to provide means of fastening, and it surely is safer to test it as it is used rather than in the perhaps fictitious condition of strength due to skin hardness.

15 These results do not constitute a new discovery. In the literature of testing engineering, references may be found with direct bearing on the subject; but in these days of rapid progress and short-cut methods, much that is old, or that may be found only by search, is apt to be forgotten or overlooked. Comparatively few laboratories have autographic machines, and the use of the extensometer with a specimen only 2 in. long is not very satisfactory because of the small extension of so short a length of material under stress. Many otherwise well equipped laboratories have no extensometer. So much of experience in testing materials is based upon work done upon iron and steel that it was perhaps a natural assumption that the characteristics of these metals would also be found in bronzes and similar alloys and hence that methods of testing used successfully with one would yield equally safe results when applied to the other. Test results which are misleading are exceedingly dangerous; they induce a false sense of security which may result in the failure of structures and lead to the condemnation of a material which would be perfectly satisfactory if properly applied and not unwittingly abused.

16 The author wishes to acknowledge the courtesy of Dr. John A. Mathews, operating manager, and Marcus T. Lothrop, metallurgical engineer, of the Halcomb Steel Company, in furnishing the means of obtaining the excellent autographic strain diagrams reproduced in Fig. 3.

AN IMPROVED ABSORPTION DYNAMOMETER

By C. M. Garland, Urbana, Ill.

Member of the Society

In testing prime movers, the engineer often laments the dearth of efficient power-absorbing apparatus. Especially is this true in the testing of small high-speed machines, such as automobile engines and steam turbines. In many cases the number of machines to be tested is large, in fact in some instances each machine is given a b.h.p. test before leaving the factory; and in every case where a high degree of reliability is essential from the output, the percentage of machines undergoing test must be large. The attention of the writer was forcibly called to this need several years ago in the testing of a small steam turbine running at 2500 r. p. m., and through this experience the type of apparatus described below was designed and has been used with satisfactory results.

2 In the design of such a piece of apparatus, the following points were to be considered. These are enumerated in the order of their supposed importance.

a It should be free from binding or "seizing."

b It should be free from producing changes in the load, due to changes in the apparatus itself, such as change of temperature, wear or friction of parts, etc.

c It should be capable of absorbing and accurately indicating a wide range of loads, from zero to the full capacity of the machine.

d The regulation of the load should be positive and instantaneous.

e The apparatus should require a minimum amount of attention and be capable of continuous service.

f It should be self-contained, occupy a small amount of floor space, and be free from noise and the splashing of oil and water.

The American Society of Mechanical Engineers, 29 W. 39th St., New York. All papers are subject to revision.

g It should be capable of being quickly changed from one prime mover to another.

h It should require a small amount of cooling water.

3 In considering the above items, it will be noted that Items *a* and *b* practically eliminate mechanical-friction apparatus from the field, while Items *b*, *c* and *d* practically eliminate machines depending upon the friction or resistance of liquids for their operation. With these two classes of apparatus removed, there only remained the principle of magnetic induction for the construction of an efficient absorption dynamometer.

THEORY

4 From this principle we know that a conductor revolving in a field of variable magnetic intensity has an electric current induced

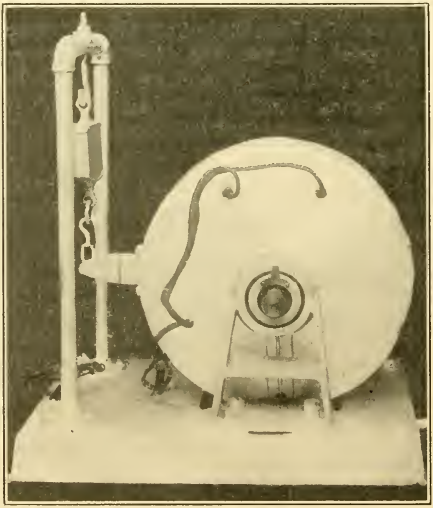


Fig. 1 Magnetic Absorption Dynamometer

in it. The reaction of this current upon the field that produces it causes a torque between the conductor and the field. There are two ways of dealing with the current induced in the conductor. In the

one, the current may be collected by a commutator or slip rings and carried off from the machine; in the other, the current, or rather currents, generated in the conductor may be allowed to remain, and, circulating in the paths of least resistance, they will ultimately short-circuit among themselves and produce heat.

5 In the first case, we have simply a dynamo mounted in a cradle. This serves as a very efficient and satisfactory type of dynamometer. There are, however, objections to its use. The currents generated must be taken care of either by water rheostats or lamp banks or utilized in the performance of work. Water rheostats and lamp banks require considerable attention and occupy space. Owing to the irregu-

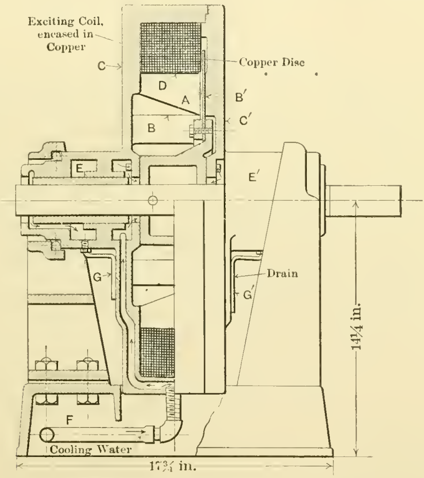


Fig. 2 End Elevation and Part Section

larities in the testing, the utilization of the current for the performance of work is in most cases impracticable. The initial cost of a testing unit of this type is necessarily large.

6 If the currents in the conductor are permitted to short-circuit themselves, the conductor is heated; the amount of heat produced is equivalent to the work absorbed by the dynamometer; and the heat thus generated may then be carried off by cooling water. This is the principle utilized in the design illustrated, a description of which follows.

DESCRIPTION

7 In brief, the dynamometer consists of a metallic disc revolving between a set of pole pieces so constructed as to produce a magnetic field of variable intensity. Fig. 1 shows the front view of a machine designed to absorb 45 h. p. at from 1200 to 1500 r.p.m. Fig. 2 is an end elevation and part section showing the construction of the dynamometer. It will be seen from this figure that it consists of a copper disc *A*, mounted on a bronze hub and revolving in front of pole pieces *B B*.′ The magnetic circuit is made up of the casting *C*, the air gap and the cover plate *C′*. The castings *C* and *C′* are bolted together and carry

Fig. 3 Left Half of Field Casting Shown in Section in Fig. 2

the exciting coil *D* and the bearings *E* and *E′*. The magnetic yoke, made up of castings *C* and *C′* carrying the field coil and disc, is supported in ball bearings, and is prevented from rotating with the disc by the spring balance shown in Fig. 1. This latter measures the pull or torque between the rotating disc and the stationary yoke.

8 The magnetizing coil is encased in copper, the terminals being carried out through holes in the casting *C*, which are carefully sealed after the coil is in place.

9 The heat generated by the short circuiting of the eddy currents generated in the copper disc, is carried off by the cooling water which

enters through the base connection at *F* (Fig. 2) and passes up through the bearings into the field casting. It then passes out through openings which are not shown in the illustration. This water not only carries off the heat generated, but serves as a lubricant for the bearings. That which passes through accumulates in the central chamber *E*, and is discharged at the base of the machine through the drains *G G′*.

10 Fig. 3 is a detail drawing of the left half of the field casting *C*, shown in section in Fig. 2. It will be seen that there are six poles in the machine. The circulating water enters at *I* and leaves through the port at *J*. Similar ports are provided in the cover plate *C*, Fig. 2.

OPERATION

11 In operating, the engine under test is directly connected to the dynamometer shaft by means of some form of flexible coupling, the cooling water is turned on and the engine is started. After normal speed is reached, the load may be thrown on by energizing the field coil. The amount of current and consequently the torque or pull on the spring balance is regulated by a rheostat connected in series with the coil. After running a few minutes, the quantity of cooling water is adjusted so that the temperature of the machine does not exceed 150 deg. fahr. In larger machines the coil may be wound with asbestos-covered wire and the temperature permitted to reach 212 deg., so that the cooling water is evaporated within the dynamometer. This reduces the quantity of cooling water required about 75 or 80 per cent.

12 The normal working temperature having been reached, the load on the machine remains absolutely constant, provided the line voltage is constant, for the mechanical friction, which is the bearing friction of the revolving disc, is small and practically constant, and changes in temperature due to changes in the supply of cooling water also affect the load on the dynamometer very little. The regulation by the rheostat is instantaneous and positive. When the dynamometer is driven by a smooth-running engine, the torque as indicated by the spring balance will not show a variation of $\frac{1}{8}$ lb., while the balance is sensitive to less than 1/16 lb. This indicates an accuracy that is not necessary even in the most refined testing work.

RELATION BETWEEN SPEED AND TORQUE

13 In the case of the present machine the torque is almost pro-

portional to the speed and is maximum at about 600 r. p. m. From this point the torque proPs off about 15 per cent at 1200 r. p. m., and remains almost constant from 1200 to 1500 r. p. m.

14 The torque depends upon the speed, number of poles, thickness of air gap, thickness of the copper disc, shape of the copper disc, and shape and spacing of the pole pieces. By varying the number of pole pieces, and the thickness of the copper disc, the point of maximum torque on the speed-torque curve may be shifted anywhere from 25 r. p. m. to 2500 r. p. m.

CONCLUSION

15 This type of dynamometer is well adapted either for the test ing of high-speed motors with a wide variation in speed, such as the automobile engine, or for the testing of slow-speed apparatus having a small variation in the speed. It can be built in practically any size from 10 h. p. up. The principal disadvantage is the high initial cost, although this is not an item where serious and continuous testing work is going on, as in factories or in the laboratories of technical schools, for the labor saved and the increase in capacity resulting through the use of the machine will in a short time more than pay for the initial outlay.

16 The efficiency, which may be expressed as the ratio of the energy absorbed by the dynamometer, minus the energy supplied to the exciting coil, divided by the energy absorbed by the dynamometer, may be made anything up to 99.9 per cent and depends upon the weight of copper placed in the coil. Ordinarily the efficiency is made about 96 per cent, or 4 per cent of the power absorbed by the dynamometer is required in the form of electrical power for excitation.

DISCUSSION

THE HIGH-PRESSURE FIRE-SERVICE PUMPS OF MANHATTAN BOROUGH, CITY OF NEW YORK

By Prof. R. C. Carpenter, Published in the Journal for September

DISCUSSION AT ST. LOUIS

Horace S. Baker[1] presented some very complete notes on the proposed high-pressure system for Chicago, an abstract of which is given herewith. After telling of that city's need of a high-pressure system, Mr. Baker illustrated the effect of such an installation on insurance rates by citing the reductions brought about in other cities, as follows:

a Philadelphia, an initial reduction of 25 cents per $100, to be followed by a 10-cent reduction.

b Buffalo, a reduction of about 3 per cent for all buildings within 500 ft. of a fire boat pipe line.

c Manhattan Borough, New York, 10 and 15 per cent advances reduced to 5 per cent; 25 per cent advance on piers reduced to 5 per cent; storage warehouses reduced from 10 to 5 per cent; "sprinklered" risks reduced from 10 to 15 per cent.

d Brooklyn Borough, New York, 10 to 25 per cent reductions in high pressure zone.

e Coney Island, New York, 25 per cent reduction.

f Cleveland, 5 to 10 per cent reduction.

2 The costs of maintaining and operating the proposed system for Chicago should not be more than the following figures, and probably much less:

[1] Engineer, Department of Public Works, Chicago.

Operating costs of three pumping stations, including interest and depreciation	$180,000
Interest on cost of distribution system, 4 per cent of $3,000,000	120,000
Depreciation of distribution system, 2 per cent of $3,000,000	60,000
Maintenance of distribution system	50,000
	$410,000

TABLE 1 COST DATA

NAME OF SYSTEM	TYPE	PRESSURE AND CAPACITY PER MIN.	TOTAL COST EXCEPT DISTRIBUTION SYSTEM	ANNUAL OPERATING EXPENSE OF PUMPING STATIONS[1]	COST PER 1000 GAL, PER MIN. CAPACITY[1]	ANNUAL OPERATING COST PER 1000 GAL. PER MIN. CAPACITY[1]
Manhattan	Electric Centrifugal Pumps	300 lb. 30,000 gal.	$670,000	$139,250	$22,333	$4,642
Coney Island	Gas Engines Triplex Pumps	150 lb. 4,500 gal.	47,000	14,186	10,444	3,152
Philadelphia	Gas Engines Triplex Pumps	300 lb. 9,100 gal.	260,000	11,978	28,571	1,316
San Francisco Estimate 1	Steam Turbines Centrifugal Pumps and boiler Plant Oil Fuel	300 lb. 20,000 gal.	622,228	34,630	31,111	1,732
San Francisco Estimate 2	Gasolene Engines Turbine Pumps Rope Drive	300 lb. 20,000 gal.	737,848	30,595	36,892	1,529
Hartford Estimate 1	Steam Turbines Centrifugal Pumps Coal Fuel	300 lb. 12,600 gal.	257,620	45,320	20,466	3,597
Hartford Estimate 2	Gas Engines Triplex Pumps	300 lb. 12,600 gal.	377,905	8,648	29,992	686
Chicago, Estimate	Steam Turbines Centrifugal Pumps	250 lb. 10,000 gal.	263,005	37,400	26,300	3,740
Chicago, Estimate	Gas Engines Triplex Pumps	250 lb. 10,000 gal.	248,112	24,626	24,811	2,463
Chicago, Estimate	Electric Motors Centrifugal Pumps	250 lb. 10,000 gal.	122,882	57,700	12,288	5,770

[1] Exclusive of Interest and Depreciation.

TABLE 2 APPROXIMATE ESTIMATE OF COST

STEAM TURBINE PUMPING STATION, 10,000 GALLONS PER MIN. PRESSURE 250 LB. PER SQ. IN.

1	Excavation:		
	Pump pit	2300 cu. yd.	
	Boiler room	3865 " "	
	Stack	565 " "	
	Conveyor tunnel	70 " "	
		6800 cu. yd. at $1	$6,800
2	Concrete:		
	Retaining walls for pump pit	616 cu. yd.	
	Boiler room foundations	453 " "	
	Stack foundations	430 " "	
	Pump house foundation	101 " "	
		1600 cu. yd. at $7	$11,200
3	Building:		
	Pump room, 60 ft. by 54 ft. =	3240 sq. ft.	
	Boiler room, 78 ft. by 84 ft. =	6552 " "	
		9792 sq, ft,	
	Assume 10,000 sq. ft. by 30 ft. = 300,000 cu. ft. at 15 cents		45,000
4	Foundations for pumps and turbines, 150 cu. yd. at $10		1,500
5	Four 2500-gal. centrifugal pumps at $5,000		20,000
6	Four 600-h.p. steam turbines at $12,000		48,000
7	Boilers, 2400 h.p. at $15		36,000
8	Chain grates, hoppers, conveyors, etc		15,000
9	Stack		8,000
10	Suction piping from city main and tunnel		6,500
11	Discharge piping		5,000
12	Steam piping		7,500
13	Condenser		6,200
14	Boiler auxiliaries, heater, purifier, pumps, etc		9,000
15	Two 20-in. venturi meters and recorders		3,000
			$228,700
	Add 15 per cent		34,305
			$263,005

3 In the light of current practice as shown in Table 1, it seems advisable to consider and estimate on the following types of pumping stations:

a Steam turbines and centrifugal pumps.
b Electric motors and centrifugal pumps.
c Gas engines and triplex pumps.

TABLE 3 APPROXIMATE ESTIMATE OF OPERATING EXPENSE

FOR STEAM TURBINE STATION, 10,000 GAL. PER MIN. AT 250 LB. PRESSURE

1	Interest, 4 per cent of $263,005	$10,520
2	Depreciation, 4 per cent of $263,005	10,520
3	Coal:	
	200 hr., 5 tons at $2.50; 8560 hr., ½ ton at 2.50	13,200
4	Oil, waste and supplies	1,500
5	Repairs	2,500
6	Labor:	
	Men, cost per annum three 8 hr. shifts:	
	1 engineer .6600	
	1 oiler .4500	
	1 fireman .3000	
	2 coal passers .5400	
	1 janitor 700	20,200
	Total	$58,440

4 For the purpose of estimate it seems proper to assume a station of a capacity of 10,000 gal. per min. against 250 lb. pressure, the working pressure to be probably 150 to 200 lb. To avoid the crippling of a station by the shutdown of any unit it seems advisable to consider units of 2500 gal.

5 In discussing the various types of installations proposed, Mr. Baker cited the advantages of each type. The direct-acting duplex pumps are rugged and ready for immediate service, but their steam consumption is large. The independent boiler plant necessary, moreover, would be costly to build and to operate.

6 The gas-engine station has the advantage of lower first cost, and no cost for power when not in operation. Though failure of the gas supply is unlikely, gasolene could be used with a change of adjustment, or by running normally on illuminating gas with low compression, which would be somewhat uneconomical. A gas-producer plant might be installed, though this is somewhat open to the same objection as the boiler plant.

7 Though electric motors are supplied from an outside source, the large number of generating stations and feeders makes the electric supply as reliable as the gas supply. The first cost and the operating expense of an electric station are low, though the standby charge is high.

8 Connecting the system to standpipes and sprinkler system

TABLE 4 APPROXIMATE ESTIMATE OF COST

Approximate Cost of Gas Engine Station, 10,000 gal. per min., 250 lb. pressure

1	Excavation:		
	Retaining wall	68,400 cu ft.	
	Main pit	58,089 " "	
	Engine foundations	5,096 " "	
	Pump foundations	7,056 " "	
	Tunnel	5,496 " "	
		144,137 cu. ft.	
		= 5,339 cu. yd. at $1	$5,339
2	Concrete:		
	Retaining wall	11,520 cu. ft.	
	Retaining wall footing	23,040 " "	
		34,560 cu. ft.	
		= 1,280 cu. yd. at $7	8,960
3	Building: 82 ft. by 79 ft. = 6478 sq. ft. by 30 ft. = 194,340 cu. ft. at 15 cents		29,151
4	Foundations for pumps and engines, 450 cu. yd. at $10		4,500
5	Seven 1500-gal. triplex pumps, for 250 lb. pressure at $8900		62,300
6	Seven 300-h.p. gas engines at $10,000		70,000
7	Freight and erection		7,000
8	Suction pipes from city main and tunnel		6,500
9	Water discharge pipes		5,000
10	Gas connections		8,000
11	Air compressor plant		2,500
12	Gasolene tanks and piping		3,500
13	Two 20-in. venturi meters and recorders		3,000
			$215,750
	Add 15 per cent		32,362
			$248,112

TABLE 5 ESTIMATE OF OPERATING COST

Gas Engine Station

1	Interest, 4 per cent on $248,112		$9,924
2	Depreciation, 4 per cent on $248,112		9,924
3	Gas: 200 hr. at 18 cu. ft. per h.p. at $0.85 per M		6,426
4	Labor: 3 engineers at $2200 =	$6600	
	6 asst. engrs. at 1500 =	9000	
	1 janitor at	600	
			16,200
5	Oil, waste and supplies		1,000
6	Repairs		1,000
	Total		$44,474

TABLE 6 APPROXIMATE ESTIMATE OF COST

ELECTRIC PUMPING STATION, 10,000 GAL. PER MIN. PRESSURE 250 LB. PER SQ. IN.

1	Excavation:		
	Pump pit	63,936 cu. ft.	
	Retaining wall footings	8,640 " "	
	Pump foundations	2,048 " "	
	Building wall	1,692 " "	
		76,316 " " = 2,826 cu. yd. at $1	$2,826
2	Concrete:		
	Wall of pump pit	15,264 cu. ft.	
	Footings	7,892 " "	
	Bldg. foundation wall	920 " "	
	Bldg. foundation footings	329 " "	
		24,405 cu. ft. = 904 cu. yd. at $7	6,328
3	Building:		
	Pump room, 36 ft. by 56 ft. = 2016 sq. ft.		
	Switch room, 16 ft. by 56 ft. = 896 sq. ft.		
		2912 say 3000 sq. ft. by 30 ft. = 90,000 cu. ft. at 15 cents	13,500
4	Foundations for pumps and motors, 150 cu. yd. at $10		1,500
5	Four 2500-gal. centrifugal pumps at $5000		20,000
6	Four 600-h.p. 3-phase induction motors at $10,800		43,200
7	Suction piping from city main and tunnel		6,500
8	Discharge piping and valves in station		5,000
9	Switchboard and wiring in station		5,000
10	Two 20-in. Venturi meters and recorders		3,000
			$106,854
	Add 15 per cent		16,028
	Total		$122,882

in buildings had been recommended in Chicago and is the practice in Winnipeg, Man., and Providence, R. I., and also with the gravity system in Newark, N. J., Worcester and Fitchburg, Mass. The fire systems of New York City and Philadelphia are not connected in this way. The objection to these connections is that great loss of water might result from broken pipes in the buildings. This could be avoided, however, by placing a controlling valve in a brick chamber outside the curb.

TABLE 7 APPROXIMATE ESTIMATE OF OPERATING EXPENSE

ELECTRIC PUMPING STATION

1	Interest, 4 per cent of $122,882	$4,915
2	Depreciation, 4.3 per cent of $122,882	5,284
3	Power bill:	
	Ready-to-serve charge, $25 per kw. = $37,500	
	$0.005 per kw. per hr., 200 hr. of full load $1,500	39,000
4	Labor, 3 shifts:	
	3 engineers at $2200 $6600	
	6 asst. engineers at 1500 9000	
	1 janitor at 600 600	16,200
5	Miscellaneous: oil, supplies, etc	1,500
6	Repairs	1,000
		$67,899

TABLE 8 ESTIMATED COST OF PROPOSED CHICAGO SYSTEM
MAINS, VALVES AND HYDRANTS

DISTRICT NO.	COST
1	$477,508
2	329,321
3	152,018
4	128,457
5	109,178
6	314,569
7	82,791
8	178,420
9	146,432
10	118,916
11	113,268
12	85,852
13	75,918
14	175,811
Total	$2,488,459
Engineering and contingencies	373,269
	$2,861,728
4 stations at $250,000 =	1,000,000
	$3,861,728

No allowance made for land.

River crossings are assumed to be made as follows: (*a*) North branch in present Grand Ave. water pipe tunnel; (*b*) Main River in proposed LaSalle St. water pipe tunnel, to be built by Chicago Railways Company; (*c*) South branch in present Harrison St. water pipe tunnel.

TABLE 9 HIGH-PRESSURE FIRE SERVICE IN THE UNITED STATES

City	Estimated Population	Date of Installation	Source of Pressure	Gal. per Min.	Max. Pressure, Lbs.	Lineal Ft. of Mains	Sizes of Mains, Ins.	No. of Hydrants	Total Cost of System	No. of Acres	Cost per Acre	Connection with Building	Effect on Insurance Rates
Atlantic City	40,000	Proposed	1 Station Elec. Turb. Pumps	7,000	225	38,590	8–14	82	$187,272	306	$612		
Baltimore	575,000	Proposed	Pump. Sta.			75,900	10–20		*397,999	360		Standpipes on Buildings	
Boston	620,000	1898	Fire Boat	6,000	200	4,700	12	14	30,080	65	463		
Brooklyn	1,400,000	1906	2 Pump. Sta. Elec. Turb. Pumps	32,000	300		8–20		1,384,500	1420	975		
Buffalo	420,000	1897	3 Fire Boats		300	12,756	12						Reduction of $0.30 per $1000
Chicago	2,229,000												
Cleveland	480,000	Constructing	2 Fire Boats to Have Pump. Sta.	10,000	300	32,524	8–20	96	*170,000	338		May have Connection with Auto. Sprinklers.	Reduction of $0.80 per $1000 Prop.
Coney Island		1905–6	1 Station Gas Triplex Pumps	3,600	150		8–16		90,000	147	612		Reduction of 25 %
Detroit	380,000	1893	2 Fire Boats	10,000	210	25,831	8–10	95		356	135		Probably has Prevented Increase
Fitchburg	33,000		Gravity†		180	28,250	8–16		50,000	346	144	Boiler Feed, Elevators and Sprinklers	Prevented Increase
Hartford	98,000	Proposed	1 Station	10,000	300	53,430	8–24	198	796,277	731.3	1089	No open Connection	
Lawrence	75,000	1906	Gravity †		134	10,200	10–12	39		120			No change
Milwaukee	340 000	1889	3 Fire Boats	15,000	250	45,717	6–12	183		630			10% Reduction

Newark...........	290,000	1905	Gravity	3,500	165	15,000	20–30	52	135,000	303	446	Some Connection	10% Reduction
New York.......... (Manhattan)	2,100,000	1908	2 Stations Elec. Turb. Pumps	30,000	300	....	12–24	1200	3,950,400	1430	2763	Water Curtains Provided for	No change
Philadelphia........	1,500,000	1903	1 Station Gas Triplex Pumps	9,100	300	35,300	8–16	166	700,000	512	1367	None on or in Buildings	Penalty of 25% Removed‡
Providence.........	200,000	1897	Gravity †	3,472	116	29,000	12–24	89	143,136	358	400	5 Automatic Sprinklers	No change
Rochester..........	185,000	1874	2 Stations Elec. Turb. Pump, Steam Turb. Turb. Pump	9,000	140	102,960	4–20	.....	.....	.....	.....	Some Connection	Graded Reduction
Toronto...........	215,000	Constructing	1 Station Elec. Turb. Pump	14,000	300	40,000	8–20	.....	500,000	287	1742	Considering Connection	Uncertain
Winnipeg..........	110,000	1908	1 Station Gas Producer Gas Eng., Tripl. Pumps	10,800	300	15,840	8–20	.....	650,000	275	2364	Connection with Auto. Sprinkler	Uncertain
Worcester..........	138,000	.....	Gravity†	.....	165	100,320	8–30	.....	.....	1380	.....	Elevators	No change

* Exclusive of pumping station and equipment.

† System consists of extension of pipes from high service into district covered by low service.

‡ Board of Fire Underwriters have voted to reduce rates to the amount of 10 cents per $1000 = a total of $40,000, if extensions costing $150,000 are made to the system.

NOTE:—This table is taken from the report on the proposed high-pressure fire system for Hartford, Conn.

Edward E. Wall[1] outlined the proposed fire system for St. Louis, which contemplates the installation of six or eight 5-stage centrifugal pumps, electrically driven, at a station on Chestnut St., from which the fire service mains will radiate north, south and west. The supply for these pumps will be taken from the distribution system, a 36-in. main being laid directly from the Bissell's Point pumping station to the Chestnut St. station, and connected to the present distribution system by a number of by-passes. Connections will also be made between two 20-in. mains on Fourth and Seventh Sts., to the supply for the pumps, so that in case of failure of the 36-in. main, the pumps may be supplied from this source.

2 It would be practicable to draw the fire pump supply directly from the Mississippi River by building an intake, but this would probably cost more than the laying of the 36-in. main, and would necessitate a charter from the Government. It would also raise the question of obstructing navigation, since it would be necessary to carry the construction well out into the channel, to insure an ample supply of water. Supply from the river direct would also preclude all connection with the distribution system, as it would be unwise to risk the contamination of the city's water supply by river water.

3 The pumping capacity of the station at Bissell's Point will be over 100,000,000 gal. of water every twenty-four hours, which is more than twice the amount ordinarily consumed; the excess being sufficient to supply more than 30 fire-streams through 3-in. hose continuously, assuming 300 lb. pressure at the fire pumps.

4 The 5-stage centrifugal pumps proposed for the Chestnut St. station will have a capacity of 150,000 gal. per hr. each, against a pressure of 300 lb. per sq. in. It is proposed to connect the station with the power plants of the Union Electric Light and Power Company and the United Railways, so that two sources for power will be available.

5 The three discharge mains from these pumps will be 24 in. in diameter, the district supplied by them to be gridironed by a system of 12-in. mains laid on the enclosed streets and occasionally connected, at crossings only, by by-passes, that the breakdown of one main may not necessitate the cutting out of any other line. The pipe used will be cast iron, extra heavy, with bell and spigot joints, double-grooved. All fire-hydrant leads will be 8 in. in diameter.

6 The system will be under the ordinary distribution pressure

[1] Asst. Water Commissioner, St. Louis.

when the fire pumps are not in use, so that for small fires the hydrants will be available for use; when the fire pressure is put on the system, the check valves on the by-passes will prevent additional pressure from coming on the distribution system.

7 While the arrangement of machinery for the pumping station, and the details of operation, have not been definitely decided upon, it is possible that gas engines may be used instead of electric motors. The questions of automatically starting and stopping the pumps, maintaining the pressure during a fire, and the general details of operation of the station, as well as the minor points of weight of pipe, design of hydrants, etc., have all to be worked out. It is estimated that the cost of this system will approximate $3,000,000.

H. C. Henley,[1] speaking on the advantages of high-pressure fire systems, said that they were chiefly valuable for the numerous powerful streams which can be quickly brought into service and concentrated to advantage. For the prevention of conflagrations and for keeping serious fires from spreading, more powerful streams are needed than can be supplied by portable fire engines without considerable delay. To obtain such streams from fire engines, it is necessary to "siamese"

Pressure Required at Hydrant to Overcome Friction Loss

Hose Diameter		2½ in.		3 in.		3½ in.	
Hose lines		Single	Siamesed	Single	Siamesed	Single	Siamesed
Smooth bore nozzle		1¼ in.	2 in.	1¼ in.	2 in.	1¼ in.	2 in.
Length of hose line, ft.	100	121	139	92	101	84.5	88
	150	139	170	99.5	113	87.5	93.5
	200	158	201	107	125	91	99
	250	176.5	232	114.5	137	94.5	104.5
	300	195	263	122	149	98	110
	400	232	325	137	173	105	121

For the 2-in. nozzle it is assumed that two hose lines of the length given are siamesed together.

two or more lines into one nozzle, requiring considerable time; and if a change in the location of engines becomes necessary, considerable time is again lost in re-assembling the hose lines.

2 The high-pressure system permits the use of hose of large diameter—3 in. and 3½ in.—and direct connection to hydrants furnishes a supply to nozzles of large area, without the necessity of siamesing

[1] Chief Inspector, St. Louis Fire Prevention Bureau.

two or more hose lines. The 2-in. nozzle is best adapted for use with high-pressure systems, this nozzle, under 75 lb. nozzle pressure, discharging approximately 1000 gal. per min. A nozzle of this area provides very effective service, as the loss of pressure, due to friction in fire hose, decreases as the area of the hose is increased. The data given in the table are derived from experiments by John R. Freeman, and show the pressure required at the hydrant to overcome friction loss in hose streams of various lengths and maintain 75 lb. nozzle pressure, the nozzle being at the same level as the hydrant.

3 High-pressure systems should be considered as auxiliary protection and there should be no attempt at abandonment of engines or other apparatus.

4 Direct connection from a high-pressure system to interior standpipes, sprinkler equipments and open sprinkler systems, should be made through siamese connections and not through direct pipe connection.

5 The inability of portable steam fire engines to furnish a stream efficient to cope with serious fires is made apparent by tests made by the engineers of the National Board of Fire Underwriters. The steam fire engines for test were picked at random from the equipment of many of the best city fire departments in the country.

Number of engines tested	102
Nominal capacity, gal	69,800
Actual capacity, gal	55,900
Percentage of efficiency	80

In many cases the efficiency of individual "steamers" is less than 50 per cent.

Edward Flad. It appears to me that a cast-iron pipe is rather dangerous for high pressure. A cast-iron pipe tested under 300-lb. pressure will often break at 75 lb. A wrought steel pipe is much more reliable, and if properly coated, should last 25 or 30 years under ordinary conditions. If steel pipe is absolutely reliable we could afford to relay it at the end of 25 years rather than to use cast-iron pipe, which is liable to break.

2 In answer to a question by Mr. Flad as to the flexibility of the joint used in Baltimore, Professor Carpenter replied that it is flexible,

in the sense that it can be laid at an angle; it is not flexible as far as change of form is concerned.

H. S. Baker asked what kind of steel pipe would be used in Baltimore, Professor Carpenter answering that it is extra heavy steel-welded pipe, $\frac{7}{16}$ in. thick, the ends being expanded into semi-spheres, an 8-in. or 12-in. pipe being expanded just enough to get a ring in it, and the whole is bolted on the outside by external bolts, very like a steam pipe.

Prof. H. Wade Hibbard. It is a fact that a cast-iron water main has been in satisfactory use in city service for twenty years, and then a piece has blown out. It seems to me that the use of cast-iron pipe should be prohibited for this special emergency purpose of fire protection on account of its unreliability. In fact, in one of the high-pressure systems using cast-iron mains, leaks have been known to take place and the pumps to run for a considerable interval, some hours, I will say, and the pressure could not be maintained under test, until it was finally discovered that the water had been pouring out into a very large excavation and flooding it, unknown to those operating the pumping station. Steel will show approaching deterioration as cast iron will not.

2 Steel pipe ought to be good for thirty years of service. That period of service should be sufficient, and cities having such pipe should then be willing to replace it, having had more reliable protection during that period of years, than cast-iron pipe could possibly give.

H. C. Henley asked if there had been any attempt made to prevent the pipes from deteriorating through electrolysis, Professor Carpenter answering that the Baltimore system is a continuous metallic structure, from one end to the other, and he believed would be thoroughly protected from electrolysis; or at least, better than by any other system.

E. E. Wall. It is a fact that actually and not figuratively, steel pipe must be handled with gloves when it is laid, because the coating has to be very carefully preserved and can hardly be repaired if it is broken in handling before the pipe is laid. This is a very serious objection to the laying of steel pipe on account of exposure to corrosion after it is laid.

W. H. Reeves. Owing to the magnitude and prominence of these plants, the pump performances should be of interest to those desiring information on centrifugal and turbine pumping machinery. The highest achievement in the art of building machinery of this class is accuracy in design. Without accuracy in design it is not possible to secure the maximum efficiencies within reach. A closely designed pump should deliver exactly its contract number of gallons against the contract pumping head, and the capacity should not run over nor under. From a pump builder's point of view the misfortune of falling short of the contract capacity needs no discussion here, but the other misfortune of running over on capacity may not be so clearly understood. One effect of running over is an overload on the motor, engine or steam turbine driving the pump, and another result is that the average efficiency of the equipment in daily operation is below what it should be, for if it runs over in capacity its maximum efficiency does not occur at its contract capacity.

2 It will be noted that each of these pumps had a contract capacity of 3000 gal. per min., against a total head of 308.66 lb. per sq. in. Table 2 shows the performances of the five pumps at the South Street pumping station. This table does not show the averages, but it will be found that each pump averaged approximately 3761 gal. per min. against a mean total head of about 313.1 lb. per sq. in. Although the head was about 5 lb. above the contract condition, the pumps exceeded the contract capacity by about 25 per cent. This, no doubt, caused the motor overload mentioned in Par. 64. The contract conditions implied 540 h.p. actually delivered, and at the guaranteed pump efficiency 770 b. h. p. would be needed. The delivered work under test was 686 h. p., and according to the test efficiency of $72\frac{1}{2}$ per cent, 946 b. h. p. was used, that is, approximately 23 per cent excess motor load.

3 There appears to be no data on tests made at the contract conditions. As the pumps were tested at a great excess in capacity it is quite probable that the efficiency would have been lowered several points if the pumps had been throttled to the agreed capacity and head. The tests as per Table 2 show about 686 h. p. delivered and 946 b. h. p., or a pump loss of 260 h. p. For a considerable range it is probably safe to assume this 260 h. p. loss to be fairly constant. Assuming this to be correct and adding this loss to the 540 h. p. delivered represented by the agreed contract conditions, would give 800 b. h. p., thus showing a pump efficiency of but $67\frac{1}{2}$ per cent. If these pumps had been accurately designed, undoubtedly they would

have shown as high efficiency under the contract conditions as was obtained with excess capacity condition.

PROF. E. L. OHLE. There seems to be quite a difference in opinion among engineers as to the reasons for the variation in efficiency of the pumps when working singly and in multiple. It seems to me that the reason is the one suggested by Professor Carpenter. It is practically impossible that all should work at the same speed, as they are independently driven. If then the pressure in the main should exceed the pressure which any pump was capable of delivering, the runner of that pump would simply revolve without delivering any water. This seems to be borne out by the experience of one pump builder, as stated by J. J. Brown.

THE AUTHOR. The discussion of the paper has been so voluminous that there is really but little needed from the author. In most of the discussion additional information of value has been contributed which I am sure will be appreciated by members of the Society.

2. The difficulties in connection with an installation of the kind described in the paper, involving a complete system of piping and hydrants capable of withstanding high pressures, as well as the necessary pumping machinery, are well brought out. I think the general conclusion will be that the piping difficulties to be overcome, especially when cast iron is employed, are very serious and require special skill and the best of material. Attention has also been called to the fact that the city of Baltimore has adopted a system in which steel pipe is employed in order to overcome the difficulties due to the breakage of cast-iron pipe.

3 The discussion has disclosed the construction of several stations in which the motive power has been obtained from gas engines, and the advantages, disadvantages and expense of such installation.

4 It is pointed out that although the centrifugal pumps are capable of operation at the high efficiencies shown by the paper, yet at the lower heads at which they are frequently operated the efficiency would be less. I do not believe there is any serious commercial disadvantage because of that fact, since it is true that the cost of operation of a fire station is principally due to other items than the cost of power. A fire station is required to be, above all things, reliable, and it is of very little importance whether or not the pumping be done under the most economical conditions for the reason that the total cost of pumping is only a small portion of the operating expense.

5 It is claimed by one of the discussors that the test should have

been made by the city at the exact capacity called for and the efficiency should have been based on the result of such a test. This doubtless would have produced a lower efficiency than that obtained. In the light of the information now at hand, there would have been no injustice in such a requirement, but at the date of making the contract matters were different and such a requirement would have imposed a penalty on the builders, which would have been of no advantage to the city. The reason for that opinion is that at the time of taking the contract the information regarding multi-stage pumps operating at high heads was quite meagre. Mr. Sando, the designer of the pumps, secured all the data he could both in this country and in Europe. The result of his investigation led him to believe that it was to the advantage of the city and of the builders to put in a pump of such capacity that it would surely meet the requirements in that respect. It was believed that this would result in a considerable increased capacity over contract requirements. The motors were designed with an equally liberal capacity so that the machine was intended, even in the beginning, to be capable of a continuous large overload. The statement that the motors showed any evidence of being overloaded is in error, possibly because a certain remark which I made was misunderstood. It strikes me that the city is the principal gainer by such a system of design and that as a consequence it owns considerable more pumping capacity than was called for in the specifications, and so far as I know, without extra cost.

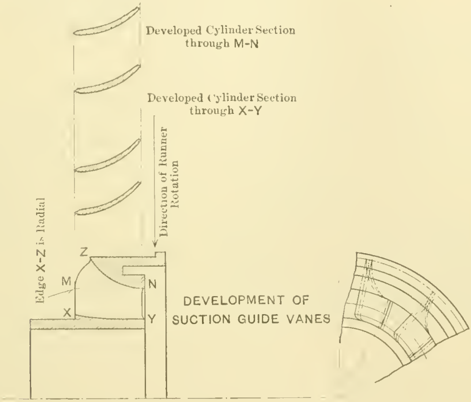
6 I believe that with the present data it would have been possible to design both pumps and motor to carry 25 per cent less load with the same efficiency as was obtained by the larger pumps and motors. In that case, a test at the specified capacity would have been a fair one.

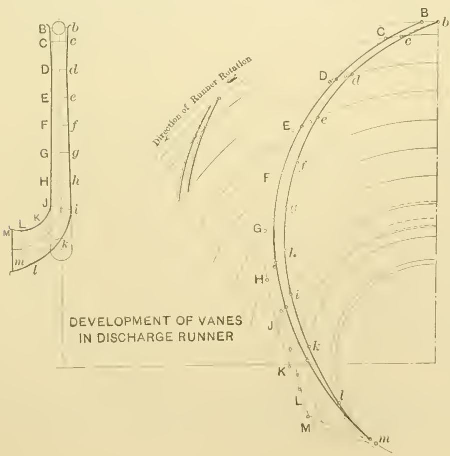
7 The interesting question brought out by these tests regarding the higher efficiency obtained with a single pump as compared with all the pumps discharging into the main, has not been satisfactorily answered. Such results, however, seem to have been noted by every engineer who has made similar tests.

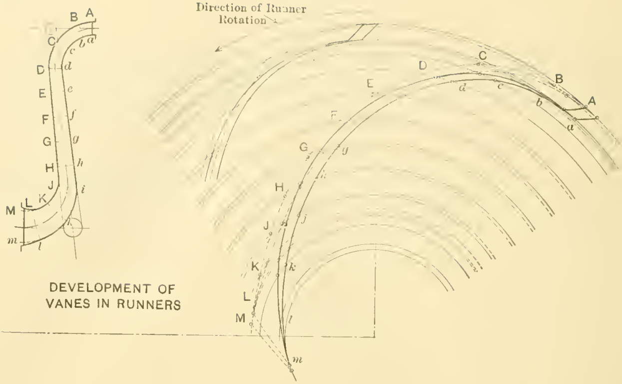
8 In the paper I made one suggestion which I believe to be of importance. I have since thought that the variation in construction or in detailed shape of the discharge volume might possibly account for some of these differences. It is hardly possible that all the pumps can be made exactly alike and small inherent differences, which would be obliterated in the operation of all the pumps together, might account for the higher efficiency of the pumps operating singly. As

suggested by Mr. White, the measurements were of a character which did not consider the pipe resistances, and the figures given apply to the delivery from the pump before the water was subjected to pipe resistances in any case.

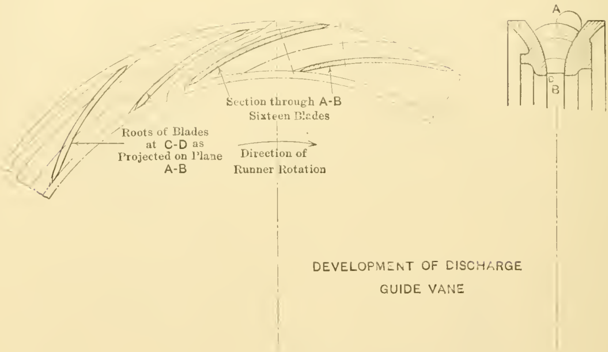
[The following curves show the development of the runners, guide wheels and guide vanes of the pumps installed in the New York high pressure pumping stations.—EDITOR.]



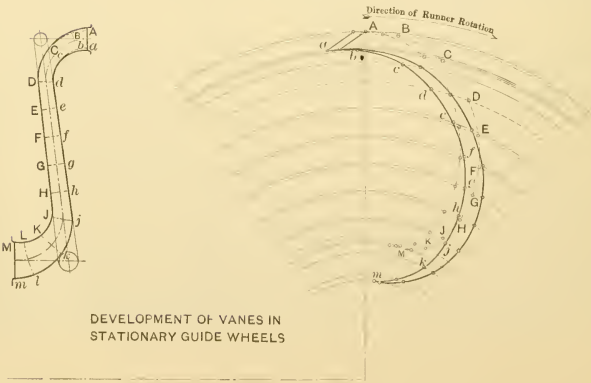




DEVELOPMENT OF VANES IN RUNNERS



DEVELOPMENT OF DISCHARGE GUIDE VANE



DEVELOPMENT OF VANES IN STATIONARY GUIDE WHEELS

LINESHAFT EFFICIENCY, MECHANICAL AND ECONOMIC

By Henry Hess, Published in the Journal for December

ABSTRACT OF PAPER

This is the description of a complete test of the relative efficiency of a lineshaft of $2\frac{7}{16}$ in. diameter, making 214 r.p.m., with bearing load due to the weight of the parts plus the tension of the belts subject to known stress by counterweighting, when running in ring-oiling babbitted bearings and when mounted in ball bearings.

Sixteen tests, each of forty minutes' duration, with belt tensions of 20 lb. to 90 lb. per inch width of single belt, were carried out. The intruments by which the electric energy consumed was measured, as well as all other instruments and the motor, were calibrated before and after the tests. The savings in power consequent on this change ranged from 14 to 65 per cent, with 36 and 35 per cent under average conditions of good practice, due to belt tensions of 44 lb. and 57 lb. per inch width of single belt respectively.

The paper gives data for determining the power savings that may be expected in various plants, as a percentage of the plain bearing shaft friction and as percentage of the total power consumption; also exact figures taking into account extra investment, depreciation, maintenance, interest on extra investment and power savings, which show that for the plant tested and described the savings represent 37 per cent per annum.

DISCUSSION

T. F. Salter. It has been long conceded that appreciable power economies were to be secured through the use of ball or roller bearings in place of plain bearings.

2 However, data which would enable the engineer to determine what savings could be expected in specific installations have been meagre as to quantity and sometimes of a questionable quality. The results obtained by the author are valuable, and are such as to encourage the use of bearings which substitute rolling for sliding friction. The following cases show the economy obtained by the use of roller bearings.

3 A Pennsylvania shoe manufacturer, with an electrically driven shop, found himself compelled to add considerable new equipment in

departments where the motors used were already overloaded. He concluded that new and large motors were necessary, but before taking action, he consulted engineers who after investigation recommended that roller-bearing hanger boxes be purchased and the old motor equipment retained. One department required 68 h.p., with babbitted boxes. The application of steel roller-bearing hanger boxes reduced the power consumption to 50 h. p., a saving of 18 h. p., or nearly 24.5 per cent, and enabled the old motors to drive the new equipment, with a small reserve for additional equipment.

4 A Baltimore belting company had a 4 7/16-in. bearing which gave a great deal of trouble through overheating. Oil bath and water jackets were tried with more or less success. A roller bearing was tried, proved successful, and forty additional bearings of various sizes were installed.

5 A wire company of Worcester, Mass., equipped their entire plant with roller bearings and have reported a 65-per cent reduction of friction load.

6 A friction disc transmission was designed by a New Jersey corporation, the requirements being that the driven shaft revolve at a constant speed. The driving shaft was subject to slight variations in speed which were to be compensated for by automatically moving the friction wheel across the face of the friction disc. The driven shaft was thus required to move laterally about $1\frac{1}{2}$ in., and to rotate at 500 r.p.m. Plain bearings with sight-feed lubrication could not be used because of their resistance to lateral motion. A special ball bearing was designed to permit a free radial and lateral movement of the shaft, resulting in an extremely sensitive and satisfactory device.

7 Roller thrust bearings are widely used wherever a thrust load or pressure parallel to the axis of a shaft is to be carried. Practically any combination of load and speed can be provided for. Nearly three years ago a bearing of this type was built for a Pittsburg steel company to operate under a pressure of 1,500,000 lb. at 100 r.p.m. As a matter of fact it carried 1,477,650 lb., applied by hydraulic pressure of 1200 lb. per sq. in. on a 32-in. piston. There was recently delivered to the same company a set of bearings the specifications of which required that they be capable of carrying 2,000,000 lb. or 1000 tons at 100 r.p.m.

8 These bearings have been applied with signal success on apparatus such as vertical hydro-electric generators, synchronous converters, frequency changers, etc., and for this work are rapidly displacing the high-pressure oil thrusts. The advantages of roller bearings are prac-

tical indestructibility, and economy of floor space (doing away with pressure pumps, accumulator, and a mass of piping required with pressure thrust); they require little attention.

9 On an installation such as a hydro-electric generating unit, it is difficult to carry on tests which would indicate by electrical instrument reading the efficiency of thrust bearings. This is due to a number of losses, the values of which it is almost impossible to determine; for instance, the loss in guide bearings, windage, variation in load on thrust bearing occasioned by fluctuations of gate openings, etc. Laboratory tests have enabled the manufacturer to be reasonably sure of the possible efficiencies which could be secured. Data obtained in this way are not as acceptable to engineers in general, however, as results secured through actual practice.

10 Believing that calculations could be made which would closely indicate the efficiency of this type of bearing, tests were made in which the rate of flow of the oil, the temperature of the oil, and the revolutions per minute of the bearing, were carefully recorded. The load was estimated and might have varied, thus affecting results. Two machines were tested, each test lasting about a week. Readings were taken at intervals of ten minutes.

11 The bearings tested carried an estimated load of 140,000 lb., at a speed of 250 r.p.m.; the temperature rise was 50 deg. fahr.; the flow of oil was 11¼ quarts (18.8 lb.) per min. From the data obtained the coefficient of friction was calculated to be 0.0016 or 0.16 of 1 per cent.

12 In the tests referred to, the heat loss, due to radiation from the oil casing of the bearing, was calculated to be 2 per cent of the total heat generated. Another test was made later with the oil casing jacketed with asbestos and the results showed a difference of 2.74 per cent.

13 These figures may be somewhat low; laboratory tests indicate that they are. I believe, however, that with a bearing of this type designed to meet the conditions of load and speed under which it is to operate, a coefficient of friction of less than 0.0025 can be obtained readily.

C. A. Graves. In tests made on something over two hundred different line shafts in various industries, I have found that a unit termed "watts per bearing" is best suited to making comparisons. This unit was obtained as follows:

2 Tests were made, stopping all the machines connected to the

shafting and measuring the power required to run the motor and shafting. The main motor belt was then taken off and the power required to run the motor free was found. The hanger bearings were counted and also the loose pulleys over which belts were passing. The difference in power, measured in watts between the shafting running free and the motor running free, was divided by the number of hanger and loose pulley bearings.

3 It developed that, on the average, loose pulleys and the hanger bearing of about the same size took approximately the same amount of power, so that the sum of the loose pulleys and hanger bearings was called the "bearings." These tests were tabulated, first, by class of industry or business, and then according to the size of the shaft. For instance, in fifty tests in machine shops, with speeds ranging from 150 to 300 r.p.m., the average power absorbed by the shaft is 49 watts per bearing. Other tests gave results shown in the table.

No. of Tests Made	Size Shaft Ins.	R.P.M.	Power Consumed Average Watts per Bearing.
43	1	400	27.1
21	$1\frac{1}{2}$	320–400	66.8
38	2	190–400	99.1
4	$2\frac{1}{2}$	200–250	108

One-inch shaft means $\frac{7}{8}$ in. or $1\frac{1}{16}$ in.

4 We were fortunate in having eight different shafts equipped with roller bearings and loose pulleys. It was found that with the shafts running from 108 to 300 r.p.m., 22 watts per bearing were required, with roller bearings on a 2-in. shaft. Taking the author's figures of tests, 3 *A* would give 5.25 watts per bearing, while 4 *A* would give 62.0 watts per bearing.

5 The author might have mentioned an additional saving obtained by using ball bearings, as smaller motors may be used to drive the shaft, thus reducing the fixed charges.

C. J. H. Woodbury. Without questioning the general conclusions of the author, I wish to inquire if the three per cent coefficient of friction referred to in Par. 31 was derived from his experiments or from other sources. The friction of a lubricated bearing varies according to the temperature of the bearing and the pressure upon it. Different oils also give different results. With light pressures, the vis-

cosity of the oil plays a large part, so much so that if the film of oil is thick, the internal resistance from the fluid friction among the particles of this oil constitutes a large element.

2 Under heavy pressures the film of oil becomes thinner, the resistance due to its internal viscosity becomes diminished and the frictional resistance of the whole bearing approaches a direct ratio of the pressure upon it. In other words, the coefficient of friction becomes very nearly constant and slightly diminishes with increased pressure as long as the lubrication is sufficient to prevent the material of the two surfaces from coming into contact with each other, after which the frictional coefficient increases, although it may not reach the conditions of a hot bearing.

Walter Ferris. The coefficient of friction of railway journals is extremely low. Without being sure of the accuracy of the statement, I believe it is nearly always below one-half of one per cent, and approaches one-quarter of one per cent. Under these circumstances, granting for the moment the correctness of the statement, the saving of friction due to the ball and roller bearings would have to be balanced carefully against additional complication, first cost, and delay in making repairs.

Fred J. Miller. The author has given no description or drawings of the bearings. The language of the paper will apply quite generally to ball bearings, whereas I understand that the test was made with specific ball bearings which had been in use for five years. I think we should have all the specific information about these bearings—including drawings—that the author is inclined to give, and a statement of the degree of refinement necessary in the making of the bearings in order to get these results.

Arthur C. Jackson. An advantage of ball bearings over plain bearings is that the speed of the shaft can be decidedly increased, permitting a reduction in the weight of the shaft and the driving pulleys, and reducing windage and other losses. The smaller driving pulleys will give an increased arc of contact for the belt on the driven pulley. In my experience in driving high-speed machinery, increasing the speed of the line shaft, which can be accomplished by the use of ball bearings, has a distinct advantage.

Chas. D. Parker. The value of the ball bearing or roller bearing seems to be conceded in a general way, but its application imme-

diately brings up the question of excessive cost, so that it is hardly considered in many cases. Data of the sort given in the paper should be highly valuable as giving confidence to engineers in recommending the use of ball bearings on a large scale, even though the cost may be high. The question cannot be decided by a single experiment. Several experiments, including tests on a shaft 400 or 500 ft. in length, would be even more valuable, especially if made on bearings that have had a few years' service under ordinary care.

2 It might be of interest to know whether the apparently high cost of ball and roller bearings is due to the high cost of manufacture or to large selling expense, which we may expect to be reduced with a more general demand for the goods.

3 With the general introduction of electric-motor drive, the belt drive from line shafts has become somewhat old-fashioned. However, as the motors have large factors of inefficiency, if the efficiency of the line-shaft belt drive can be greatly improved by the use of ball bearings, it would be of interest to know to what extent this can be done. It would probably be shown that the older method is still the more economical method in a great many instances.

Oliver B. Zimmerman. I would like to ask Mr. Hess if he has considered the application of ball bearings to countershafts which do not run the same proportion of time as the line shaft. What would be the relative return on the investment in that case, as compared with the line shaft itself? Furthermore, would it be advisable to lengthen the line shaft when the ball bearings are used; for instance, in group driving, would it be an advantage to use a line shaft 90 ft. or 100 ft. in length, as compared with a group of machines driven from 60 ft. of line shafting?

W. F. Parish, Jr. Mr. Hess's paper brings out an important point usually overlooked in comparative tests requiring great accuracy, namely, the influence of temperature and relative humidity on the power delivered, by causing variations in belt tension.

2 For comparative tests made under work-shop conditions it is advisable to have the belts made up half of cotton and half of leather, thereby eliminating the effect of humidity, which may cause variations of 12 per cent in the power delivered.

3 An English firm five years ago purchased a cotton belt to drive a dynamo, but this belt was not equal to the speed and power required of it, so a leather belt was substituted. It was decided to use the cot-

ton belt on one of the main mill drives, but it was found to be much too short. So a piece of leather belt was spliced in, the whole being, when finished, half leather and half cotton. A casing was built under it, as it was low down and in a dangerous position. The manager was annoyed to find that this casing had been built too close to the belt, no allowance being made for sagging.

4 The dampness greatly affected the leather belt, as the drive was in a low part of the mill, but the casing under the patched belt was never altered. The length of this belt never varies whether the weather is damp or dry and it is the best belt drive in the mill for steady work. Moisture has an opposite effect on leather and cotton, leather lengthening and cotton contracting with an increase of humidity, so that in the half-cotton and half-leather belt the weather effect is practically compensated for.

5 In Test 3 and Test 4, the average saving of power by using ball bearings instead of ring-oiling bearings is 36 per cent and 35 per cent, respectively, which is unusually good. It would be interesting to know what oil was used in the ring-oiling bearings during these tests and if the oil was new or old. With a very poor oil in the ring-oiling bearings the saving in power may be only partially caused by the change to ball bearings.

6 Oil and lubrication play a very important part in the economical distribution of power. Many power tests which I have made show that when very poor and cheap oil is used, a saving as high as 40 per cent can be obtained simply by using a better oil. Forty-two comparative power tests, made in small work shops or sections of large shops, show an average saving in power of 19 per cent, due to the use of a good and suitable oil. By using a good oil there will be but little increase in cost, as it can be used sparingly, so that the yearly cost for the better oil may be even less than for the poor oil. One test on a machine gear-driven by an electric motor showed a power saving of 55.5 per cent. by using a good oil instead of a poor oil and grease.

Geo. N. Van Derhoef. In the results of the tests summarized in Par. 41 of Mr. Hess's paper, the quantity of oil required to maintain ten 2 7/16-in. bearings is given as $\frac{1}{2}$ pint a day, or 150 pints per year, which is equal to 18 $\frac{3}{4}$ gal. There is probably no make of self-oiling hanger on the market today that requires anything like this quantity of oil to maintain it. Three gallons a year for ten hangers would be ample allowance for even the poorest make.

2 The item of labor charged is two hours a week, which is also

excessive even if the enormous quantity of oil specified were used. As a matter of fact, three or four hours a year should be ample time to devote to the care and attention of ten 2 7/16-in. hanger boxes.

3 The allowance of twenty years for depreciation would seem fair for babbitted bearings, as probably all of us know of bearings running in daily service for a longer period. I would like to know if Mr. Hess has any figures showing ball bearings on line-shaft service for anything like this period. As I look at the matter—and I think others will agree with me—it is not so much a matter of a lower coefficient of friction as it is of the "staying properties" under practical conditions, as distinguished from a test experiment extending over a brief interval of time.

The Author. Taking up the various points raised and the questions asked during the discussion, the author wishes to reply as follows:

2 *Percentage of Saving and Actual Saving.* A saving of power cannot be intelligently considered as a percentage of the entire driving power without full knowledge of the entire conditions. A given actual saving may be one per cent or ninety-nine per cent of a total. The saving in line-shaft journals when referred to the line-shaft loss is one ratio, and when referred to the total power consumption, is quite another ratio. So far as I am aware the literature on the subject quite generally refers to the line-shaft friction as a percentage of the total power consumption. That is misleading, since the percentage ranges from only sixteen or so in some textile mills to seventy or more in some of the rougher machine industries. In all probability the actual friction loss, bearing for bearing, does not vary in anything like so great a degree as sixteen to seventy per cent. The thing that is of real importance is not the ratio of the saving to a given whole, but the actual value of the actual saving.

3 *Estimating Power Losses and Savings.* Mr. Graves suggested that the power consumption of a bearing might be stated from experience in "watts per bearing." Such an expression would be convenient if it could be correctly applied; but the watt loss depends upon the coefficient of friction, the load and the surface speed. The coefficient of friction for a given type of bearing may be said to be fairly well known, or at least not to vary between very wide limits. That may also be said of the load; but the surface speed is made up of the shaft diameter, or rather the circumference, and the angular speed, both varying between very wide limits. So general an expression is therefore hardly possible, nor is it necessary.

4 For any given installation, the shaft diameter and speeds are known; the loads are due to the definitely determinable weight of the shaft, pulleys and belts, and to the belt pull, the last-named of which should not be allowed to exceed 60 lb. per in. width of single belt, while it certainly will rarely fall below 40 lb. The coefficient of friction for plain bearings may range from 2 to 8 per cent, with 3 per cent a very fair and general value, and $\frac{1}{8}$ per cent for ball bearings. A rise to $\frac{1}{4}$ per cent for ball bearings would indicate a poor quality of bearing.

5 An actual calculation, using the known constants of the installation in question, will always give closer results than the use of any general expression, necessarily much less accurate, such as "watts per bearing." In Par. 32 the expression for kilowatts is given as

$$Kw = 0.000{,}0059\ L\ d\ s\ \mu$$

or

$$\text{watts} = w = 0.000{,}000{,}0059\ L\ d\ s\ \mu$$

which may readily be converted to the convenient form

$$K\,w_y = \text{watts per bearing for year of 3000 hours}$$
$$K\,w_y = 0.000{,}001\ L\ d\ s\ \mu$$

6 Mr. Graves has found the "watts per bearing" to range from 27.1 to 108 in 106 tests of plain bearings. The measured losses of the test cited in the paper are under average conditions of belt pull. For the usual belt load, Test 3 and Test 4 show for the ten plain bearings (see table in Par. 33) losses in kilowatts of 0.350 and 0.405, and for the ball bearings 0.018 and 0.020, or in watts per plain bearing 30 and 35, and for ball bearings 15 and 18.

7 Mr. Graves' four tests of a 2 7/16-in. line shaft at 200 to 250 r.p.m. may be fairly compared with the author's tests of a 2 7/16-in. line shaft at 214 r.p.m; Mr. Graves' result of 108 watts per bearing, as against the author's of 30 to 35, shows how unsafe a general wattage figure is. Changing the coefficient of friction from the 3 per cent found to be approximately correct for the test cited, to 10 per cent, would raise the 30 watts per bearing to Mr. Graves' 108 watts per bearing. In reality the tests cited by Mr. Graves are confirmatory of the author's, since the former range from 27 to 108, proving that the author's values of 30 to 35 for correct belt loads and 22 to 46 for extremely light and extremely heavy loads, represent an average of good practice.

8 *Indirect Economies.* Mr. Graves has suggested that the mounting of line shafts on ball bearings will reduce the sizes of the

motors required to drive the shafts. While that is obvious, the consequent economy is greater than is at first apparent. A motor must always be selected of sufficient size to perform its work safely. As the frictional resistance of a plain bearing line shaft is apt to vary between very wide limits—27 to 108 watts per bearing, according to Mr. Graves' tests—the motor must necessarily be selected to cover nearly the maximum safety. That means a rather large motor compared with the average useful plus friction load. Not only is there thus an unnecessary increase of first cost of the motor but, more seriously, the operating cost is unduly enhanced, as it is well known that a motor operating much below its rated capacity has low efficiency and is wasteful of current. When, on the other hand, the line shaft is mounted on ball bearings, the friction load is greatly reduced, its amount is more definitely determinable beforehand, and the initially smaller motor is used nearer at its point of maximum efficiency.

9 Mr. Jackson refers to a possible increase in shaft speed due to mounting the shaft on ball bearings, resulting in decreased weight of shaft pulleys and belts and more favorable belt contacts. All of these elements in time make for decreased bearing loads and consequently still further increases in economy. Mr. Jackson has had under his continual observation during several years a number of plain and ball-bearing line shafts of medium and high speeds, and so speaks not merely from theoretical reasoning, but from actual practice and observation.

10 *Reduced Importance of Improper Belt or Rope Tension.* The great variations in belt tensions that may be brought about by weather and temperature conditions, moist and dry atmosphere, etc., have been referred to by Mr. Parish. Both leather and cotton belts, as well as fibre ropes, are subject to considerable variations from these conditions. Possibly fully as important a factor is the average millwright or mechanic. The properly stressed belt is the exception. Most belts are tightened almost to the breaking point. The work thus lost in friction in plain bearings is directly proportional to a coefficient of friction ranging from 3 to 10 per cent for those conditions; but with the low coefficient of friction of $\frac{1}{8}$ to $\frac{1}{4}$ per cent for ball bearings a relatively enormous over-stressing of the belt has but comparatively little influence in increasing the journal friction losses.

11 The ball bearing is a most important factor in belt economy, since the absence of the plain bearing friction load permits the use of slack belts and makes for greatly increased belt life. Mr. Fred. Tay-

lor showed the consequent economy most conclusively in his paper, Notes on Belting, (Transactions, Vol. 15, p. 204).

12 *Relative Efficiency of Direct Motor Drive and Ball-bearing Line Shafts.* Mr. Parker refers to the large factor of inefficiency of motors and inquires concerning the possible improvement in line-shaft belt drives due to the use of ball bearings. While in the early days of the introduction of direct-driven tools much was expected from the saving due to cutting out the line-shaft friction, it soon developed that the need for using motors equal to the maximum demand of a tool brought in greater power losses because of such motors working on an average at points of low efficiency.

13 Unless the direct application of the motor results in greater convenience of handling the machine to produce a greater output, the direct drive is not justified. In that case, the mounting of countershaft, loose pulleys and line shaft on ball bearings will result in very considerable power savings. The tests made for the author by Messrs. Dodge & Day on line shafts showed savings of 35 per cent under average conditions; extended to the countershaft and loose pulleys the savings will readily amount to more than half of the total power consumption.

14 In line with this general question Mr. Zimmerman asks whether it would be advantageous to lengthen a group-drive line shaft to 60 ft. to take a larger group involving a shaft length of 100 ft. Unquestionably that will be economical so long as other considerations than those of line shaft and line-shaft motor losses do not govern. As to the relative losses in countershaft and line shaft, it may be said in general that they will be fairly equal. It is true that the countershaft does not run as continuously as does the line shaft, but that simply involves a transfer of the loss from the countershaft hanger to the loose pulleys; only when the belt is actually thrown off does this loss cease; if the loose pulley diameter is decreased, as it should be to decrease the belt tension, the loss is lessened.

15 *Ball vs. Roller Bearing.* Mr. Graves makes inquiry concerning the relative values of ball and roller bearings and their coefficients of friction. The coefficient of friction for good ball bearings has already been given as close to $\frac{1}{8}$ per cent; for roller bearings the friction is about double, assuming always that the rollers are kept in alignment and that hard and true rollers rolling on true and hardened surfaces are used. The real advantage of the ball bearing is not the difference in friction, but its endurance and the consequent permanence of the power saving. As the correct ball bearing employs

only a single row of balls it has no length; that at once cuts out all disturbances, due to deflections of shafts or housings, that seriously affect rollers. The readiness with which the ball bearing is housed to retain its lubricant and to keep out injurious grit, as well as the small space occupied, are also advantages peculiar to it alone. The coefficients of friction cited have been determined by oft-repeated tests. They are referred to the shaft diameter so that the values are directly comparable with those of plain journals.

16 *Reasons for Ball Bearing Cost.* Mr. Parker wishes to know whether the apparently high cost of ball bearings is due to the high cost of manufacture or to large selling expense. Concerning the latter it may be said that the expense of selling ball bearings is not at all high; it is, in fact, lower than in many other lines of high-grade precision machine elements. The cost resides in the absolute necessity for precision, and the character of manufacture. Ball bearings can fitly be compared only with high-grade tools of high-grade steels. The material is a special alloy steel, relatively high in carbon, manganese, chrome and silicon; this is a combination that is very refractory under the cutting tool. After hardening, rough and finish grinding cannot be forced, as that spoils the integrity of the rolling surface. Accuracy of a high degree is essential; the unit of measurement is the ten-thousandth part of an inch. Interchangeability of a high order is not to be secured cheaply.

17 The data showing the saving in power consumption, not in percentage, but in actual consumption, that Mr. Parker asks for, are given in the body of the paper in the table in Par. 36, on lines marked "Plain Bearings measured Kw." and "Ball Bearings measured Kw."

18 *Ball Bearings on Railways.* This use of ball bearings is outside of the subject matter of the paper, but as inquiry has been made by both Mr. Ferris and Mr. Graves it may be noted that ball bearings of the same type are in regular use for main-line railways and electric railways, on the axles in the former and for both axles and motors in the latter. On the Prussian-Hessian State railways the first of these bearings are still in use, and as the result of somewhat over 400,000 kilometers' run (250,000 miles) under standard passenger coaches, show no evidences of wear.

19 In Europe, as well as in the United States, careful comparative measurements, extending over many weeks of 2-min. observations, have shown savings in electric railway power consumption of over ten per cent, with incidental decrease in motor temperature. For main-line and electric railway service the direct power saving is of less

importance than the ability to take advantage of coasting; this saving may frequently rise to 37 per cent. The chief economy lies not in power saving, but in saving of lubricant, attendance, cost of renewals and, in electric railway operation, the keeping of the equipment more in service, and less in the repair shop for renewing bearing linings and rewinding armatures that worn plain bearings have allowed to sag into the polepieces.

20 *Type of Bearing Under Discussion.* The author purposely confined the paper to a report of results of tests made for him

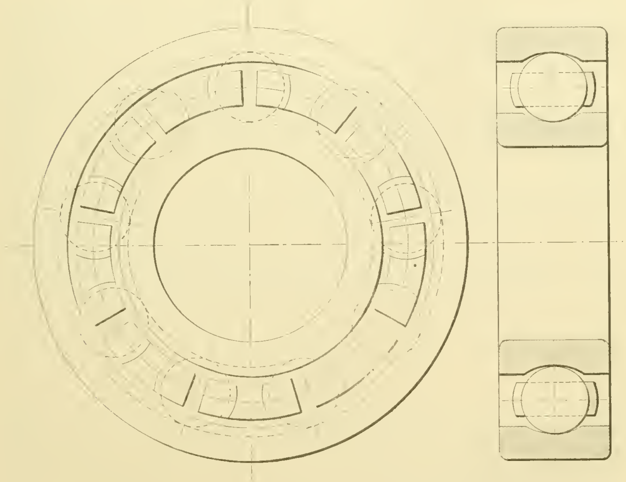


Fig. 1 Elevation and Cross Section of the Hess-Bright Ball Bearing

by Messrs. Dodge & Day, preferring to bring out the engineering value and economic value to be expected of correctly made, correctly selected and properly mounted ball bearings. As Mr. Miller has asked for information concerning the specific ball bearing involved in the test it is proper to say that it is known in the United States as the Hess-Bright or DWF, and in Europe generally as the DWF.

21 Fig. 1 illustrates the ball bearing proper, in cross section and in elevation. It will be seen to consist of an inner race, an outer race, a series of balls, all of special steels hardened throughout, and a cage or

separator for the balls. The ball tracks have curvatures approximating the ball outline, the inner track very closely, the outer track slightly less so. The contact between balls and tracks is on a plane at right angles to the axis of the shaft, thus providing only one point of contact of the ball with each track. The sides of the races are continuous, with no interruption at any point for filling in the balls; that ensures absolutely smooth rolling of the balls and the absence of any possible contact with the edges of filling openings. In lieu of side interruptions or filling openings for the balls, assembly is by eccentric displacement of the two races, filling in balls through the wider space at one side, bringing the races into concentric relation, spreading the balls evenly and retaining them in proper position by the separator.

22 As to the refinement necessary in the making of these bearings, to which Mr. Miller kindly refers from his own observations, I would say that balls must be true to shape and to size within a limit of 0.0002 in. The bearing bore is held within a tolerance of 0.0002 in. +, and 0.0004 in. −. The outside diameter is held within 0.0006 in. +, and 0.0012 in. −, according to size. The width is held within 0.02 in. −. Each finished bearing is gaged for trueness of rotation with reference to the bore, and for trueness of the outer race on the ball circle. Each race is tested for uniformity of hardness, referred to a standard, at four points on each side, or eight per race; the sclerescope is used for this purpose, and that in turn is occasionally checked by the Brinnell, as well as the Turner and the Howe hardness test apparatus.

23 Lest it may appear that these refinements are not necessary, it may be well to say that the knowledge of their necessity has been acquired at great cost; also that only to the most painstaking care in material, treatment and workmanship is the success of the ball bearing due as an every-day reliable element of mechanism. A knowledge of proper proportions for various conditions of load, speed, shock, etc., is, of course, also essential.

THE BEST FORM OF LONGITUDINAL JOINT FOR BOILERS

By F. W. Dean, Published in The Journal for October 1909

ABSTRACT OF PAPER

This paper deals specially with the defects of the usual form of butt joint used on the longitudinal seams of boilers, in which the inside strap is wider than the outside strap. It gives some history of the joint and discusses some of its defects and suggests a substitution for this form.

While stating that there has never been an explosion of a horizontal return tubular boiler built with the ordinary form of butt joint, the author gives an example of the rupture of such a joint that would have resulted in an explosion. The joint recommended as a substitute for this, is one that has the inside and outside straps of the same width, but the outer row of rivets is made with a wide pitch and the straps are made sufficiently thick to stand caulking between the widely pitched rivets.

Ordinarily the efficiency of this substitute joint is from 84 to 85 per cent, but it can be made as great as that of any other form of joint, if the pitch of the rivets is wide enough, in which case the straps would have to be thicker than would otherwise be necessary.

DISCUSSION

Reginald P. Bolton. The form of longitudional joint for boilers, which Mr. Dean has described as the best, is as old as the time of Brunel, and was tested by him in 1838, and again by Longridge in 1857. It is a double-welt triple-riveted joint, omitting alternate rivets in the outer strip, and it has the defect of undue distance for calking between the outer rivets. It is not so good a joint as it would be when the triple riveting is continued, instead of omitting the alternate outer rivet. The other form of joint to which Mr. Dean refers, in which the inside welt was wider than the outside welt, has stood the test of many years usage, and I do not know of any case of failure.

2 In discussing the longitudinal joint, we should not lose sight of the fact that the weak parts of every longitudinal joint are the ends, where the two shell plates unite and the circular seams meet the longitudinal joint. It is there that weakness develops in all joint construc-

tion. In explosion cases on which I have been engaged, I have found that trouble has developed at those points, and have noted that ruptures commenced there. Therefore, in dealing with the design of longitudinal joints, the essential feature seems to me to be its character where it meets the circumferential seam.

E. D. Meier. I think that the value of this joint depends largely on the diameter of the boiler that one has in mind. In a Scotch marine boiler, from 12 to 15 ft. in diameter, the joint would be an excellent one, especially with the scalloped edges mentioned by Mr. Dean. That is a very troublesome thing to do, but in addition to the advantage of the scalloped edge which Mr. Dean cited, there is the further one, that it modifies the tendency, common to such joints, to buckle at the point where the sheets come together. The butt joint is stiffer there than any other part of the shell and with a change in the pressure and temperature the buckling ultimately tends to impair the joint.

2 With a small boiler, 36 in., 42 in., or 48 in., in diameter, the joint is too large a proportion of the total circumference, and this action would become worse. That buckling action is distributed by making the butt plates as thin as possible, and making the inside one longer than the outside one.

3 The one joint that was not considered in the paper—the welded joint—will be an ideal one when we can be sure of a weld that will give 95 per cent efficiency. The difficulty will be to test it. We do know, however, that when we rivet a joint and do it honestly, we have something that can be relied on. Much will depend on how the material is chosen and how the work of laying up and riveting is done. The joint should be made by carefully bending the butt straps at a red heat to the true curve, and rolling the plate itself true to template. This will make as perfect a joint as possible. For a large diameter of boiler, I think the joint advocated by Mr. Dean, especially if the edges are scalloped, is an excellent one, but for smaller diameters I prefer the old joint.

4 Two other points must be considered: first, how the caulking is done, as in many sheets the initial fracture is caused by bad caulking; second, what sort of metal was used, for unless the chemical analysis of the plates as to minimum of injurious metalloids is firmly insisted on, trouble is sure to follow even in the best proportioned joints.

Prof. A. M. Greene, Jr. Mr. Dean is probably aware that in the 1893 report of the Chief of the Bureau of Steam Engineering of the

Navy, it is shown that the boilers intended for the New York, the Columbia and the Minneapolis, were all designed on the same plan as that which Mr. Dean recommends. The illustration in the paper is almost exactly similar to those in the report. These boilers were all installed and have given entire satisfaction.

2 Locomotive engineers, however, are using the unequal length butt strap quite extensively. I know of locomotives in which two rows of rivets were placed outside of the outer butt strap, and I do not know of any failure of such joints. If it is a case of getting increased efficiency, and still having the outer butt strap arranged for a caulking distance, I do not see why we should depart from the method of unequal straps to use the equal strap arrangement which cannot give such high efficiencies.

William A. Jones. I wish to point out the tension which exists in the outer row of rivets and its effect on the drum shell. This should have an important part in determining whether the form of joint which Mr. Dean recommends is really better than if the outer butt strap were cut back one row of rivets on each side, so that the rivets at their caulking edges would be close together.

2 We probably all agree that rivets are more reliable in shear than they are in tension; that the closer and more firmly the edge of the outer butt strap is held down, the less caulking will be required and so the less possibility there will be of injuring the shell plates by caulking the butt strap in the shop, and the more remote will be the probability of subsequent leaks, prompting inexpert men to caulk them again later.

3 If we assume that the inner rivets are about 3 in. apart, then the outer rivets shown in the joint which Mr. Dean recommends will be about 6 in. apart, and each rivet will be holding an area of butt strap of from 15 to 20 sq. in., which, at 200 lb. pressure, will require from 3000 to 4000 lb. tension per rivet. In addition, each of these rivets will be required to hold the caulking for an edge about 6 in. long, and the caulking will have an advantage over the rivet of about 2 to 1, due to the leverage which it has because the rivets are back from the edge. It does not require much thought to see that these rivets would be better able to do this work if they were twice as close together.

4 The joint which Mr. Dean has shown has five rivets in double shear on each side, in a length equal to the pitch of the outer rivets, so that ten times the area of one rivet is the total area in shear in this length. If, on the other hand, the outer butt strap were cut back so

that the rivets at its edge would be close together and the outer rivets were in single shear, then the total area in shear would be only one-tenth less, and the proportion of the circular tension transmitted by the rivets in single shear could not be more than 11 per cent of the total in this case.

5 I understand that it is in an effort to improve the action of this 11 per cent of the force involved that this wide outer butt strap is recommended, and that where four rows of rivets are used instead of six, this proportion may rise to 20 per cent. In any case, the slight in the shell plate is less, I believe, than the bending tendency which the tension would produce in the rivets, due to pressure on the wide outer butt strap.

6 Let us consider the forces acting upon a rectangular area of plate in a drum shell under pressure. The circular tensions acting tangentially at the edges of this area are equal in intensity, but act at an angle to each other, so that each has a component normal to the chord of the area considered. These normal components exactly balance the pressure acting on that chord. When the area considered embraces a half-circle, the normal components become equal to the circular tension.

7 In the case of the outer butt strap, if all the circular tensions of the drum could be transmitted to the outer butt strap by rivets at its extreme edge, the shear of these rivets alone would hold the outer butt strap to the drum, and the components of the shears normal to the chord would just balance the steam pressure on that chord, so that no tension in the rivets would be necessary, except for caulking. Moving the rivets back from the edge of the butt strap makes the shear act more nearly parallel to the chord, while it does not diminish the chord, so that shear alone will no longer hold the butt strap in place, and tension must be developed in the rivets to make up the difference.

8 Transmitting part of the circular tension through the inside butt strap further increases the tension on the rivets, due to pressure, but the additional tension in this case maintains the curve in the inner butt strap by stitching it to the surface which receives the pressure and the reaction of the tension at the inner ends of these rivets is thus provided for.

9 In the case of the outer rivets of the joint which Mr. Dean shows, reaction of this tension at the inner ends of the rivets must be absorbed by an abrupt change in direction of the circular tension at those points, tending to produce corners in the drum shell in order to satisfy the triangle of the three forces formed by the tension on the rivet, the

tangential tension to the right, and the tangential tension to the left. If we assume a 42 in. drum, 200 lb. steam pressure, 6 in. pitch of outer rivets, each of which takes in tension the pressure of 20 sq. in., we have 4000 lb. tension in each rivet due to steam pressure, the inner ends of the rivets being anchored by an abrupt change in direction of about 9 deg. of 25,200 lb. circular tension.

10 Evidently, this abrupt change of direction of the total circular tension may readily distress the plate more in the form of joint which Mr. Dean recommends than in the usual form of joint with the narrow outer butt strap, even though a very small part of the circular tension is transmitted through a rivet in single shear.

11 Mr. Dean's statement that he believes there has been no case of failure of butt strap joints, would indicate that there was nothing wrong with the established form using the narrow outer butt strap. Certainly the remedy proposed seems more objectionable than a rivet in single shear.

Sherwood F. Jeter.[1] It seems that all engineers design joints with reference to their weakest point, that is, provided the joint was to be ruptured in a machine. Of all explosions that to my knowledge have been due to ruptures, none of them have occurred in the theoretically weakest part of the joint. Most explosions due to rupture of the sheet have occurred near the joint and were apparently due to flexure of the metal, which had destroyed its life at the particular point of rupture.

2 I believe that there is a great need for an investigation as to what causes the rupture of the plate, and for other than machine tests of different kinds of joints. An account in Power states that there have been four ruptures of butt-strap joints of a nature similar to what was previously alluded to as a "lap cracking" of the joint. From the great number of lap joints in successful use for twenty-five years or more, it may be judged that something besides a mere lapping of the plates causes such defects.

The Author. There is very little for me to say in closing, as my views have been fully set forth in the paper. I am interested in the history of this joint as stated by Mr. Bolton. I first knew of it in 1889; it is shown in Thomas W. Traill's book on boilers, and a table of sizes of parts is there given.

[1] The Bigelow Co., New Haven, Conn.

2 Several of the speakers express doubt as to the tightness of the joint on account of the wide spacing of the outer row of rivets. There should be no doubt of this kind, for too many of them are in use. I know of one joint with $1\frac{1}{4}$-in. rivets in 1-in. straps on a pitch of $9\frac{1}{8}$ in., and another with $1\frac{3}{16}$ in. rivets in a $\frac{7}{8}$-in. strap on a pitch of $8\frac{3}{8}$ in.

A REPORT ON CAST IRON TEST BARS

By A. F. Nagle, Published in The Journal for Mid-October 1909

ABSTRACT OF PAPER

This paper is designed to show engineers that test pieces, whether cast in separate molds or in the same mold as the main casting, are not *perfect* indications of the character of the iron in the main casting. In other words, uniformity of results is not found in practice where we know of no reason why they should not be uniform. These test bars were used in the construction of over 3,000,000 lb. of pumping-engine castings, involving soft and hard irons for the various parts. Tables 5, 6 and 7 would indicate a probable variation of 15 per cent where uniformity might be expected.

DISCUSSION

Prof. W. B. Gregory. The writer has recently made a large number of tests of cast-iron specimens of one-inch square cross section and with supports 12 in. apart, a few being also broken in tension. The results confirm the deductions of the author as to the relationship between breaking loads in tension and in cross bending. The ten-to-one ratio holds in these tests as in those given by the author. Table 1 gives the results of the cross-bending tests, the load being applied at the center.

TABLE 1 TESTS IN CROSS BENDING
Specimens 1 in. by 1 in., 12 in. between centers, load applied at Center.

Number	Breaking Load Lb. per Sq. In.	Deflection In.
1	2280	0.10
2	2250	0.10
3	2680	0.09
4	2410	0.09
5	2250	0.08
6	2370	0.09
7	2240	0.09
8	2310	0.08
9	2250	0.09
10	2470	0.08
11	2180	0.10
Mean	2335	0.09

2 From the specimens broken in cross bending, six were selected from which were turned tension test pieces approximately $\frac{1}{2}$ in. in diameter at the smallest section, their length over all being 5 in. The threads at the ends were $\frac{3}{4}$ in. outside diameter. The test pieces were made to fit loosely into the tension bars of the testing machine so that side stresses were entirely eliminated, and the specimens were broken in pure tension. The results are given in Table 2.

TABLE 2 TENSION TESTS

Number	Breaking Load Lb. per Sq. In.
1	22900
2	23300
3	22800
4	23550
5	24600
6	22050
Mean	23200

The ratio of tensile strength to load in cross bending is

$$\frac{23200}{2335} = 9.94$$

This comparison can be made only on the basis of averages, as no record was kept of the numbers of the specimens broken in cross bending. The six tension specimens therefore represent six of the eleven specimens broken in cross bending. Specimen No. 9 of the cross-bending tests may be taken as fairly typical of the others. A chemical analysis was made of this specimen with the following results:

Total carbon	4.04
Silicon	1.76
Phosphorus	0.562

3 The mean deflection as given by the author averaged 0.45 in. for two sets of specimens and 0.44 in. for another set. The highest value of deflection in any case was 0.50 in. Since the deflection varies as the cube of the length of specimens between supports, it follows that the deflection for specimens tested with supports 24 in. apart should be eight times the deflection for a length between supports of 12 in. On this basis the specimens tested by the writer should have

$$\frac{0.45}{8} = 0.056 \text{ in.}$$

deflection instead of 0.09 in. average as the tests showed. Can this discrepancy be explained by the difference in chemical composition or is it due to other causes?

4 This raises the question of what deflection ought to be specified for one-inch square specimens with 12 in. between supports. Some specifications have recently been brought to the attention of the writer in which the minimum deflection was placed at 0.15 in. Is this commercial cast iron or does it call for a special mixture, expensive and hard to obtain?

5 The author has mentioned that the "skin of the metal" was of no appreciable thickness. I would like to ask if he has ever tried the effect of rattling on specimens. The process of rattling will remove the sand and the skin of the metal. In this connection the results in Table 3 may be of interest.

TABLE 3 TESTS OF CAST IRON IN CROSS BENDING

Specimens round, 1¼ in. in Diameter, 12 in. Between Centers. Not Rattled.

No.	Breaking Load Lb.	Deflection In.	Remarks
1	2450	0.075	Cast in pairs on end
2	3010	0.08	" " " " "
3	2670	0.07	" " " " "
4	2580	0.14	" " " " "
5	2700	0.09	" " " " "
6	2580	0.14	" " " " "
7	2620	0.08	" " " " "
8	2430	0.075	Cast flat
9	3360	0.09	" "
10	2750	0.08	" "
11	2990	0.09	" "
12	3170	0.09	" "
13	2950	0.095	" "
14	2960	0.12	" "
15	3080	0.10	" "
16	2580	0.075	Cast on end
Mean	2805	0.093	

6 The tests given in Table 4 are on specimens of the same size as those in Table 3. The metal used was as nearly the same as the foundry could make it and the specimens were placed in a rattler and the sand and "skin" removed by abrasion. From these figures it will be seen that rattling has increased the strength, of the specimens, the increase being 3474 − 2805 = 666 which divided by 2805, gives 23.85 per cent. This phenomenon has, been noticed by other experimenters.

TABLE 4

No.	Breaking Load Pounds	Deflection Inches
1	3750	0.09
2	3330	0.095
3	3400	0.08
4	3520	0.09
5	3640	0.09
6	3640	0.10
7	2760	0.075
8	3670	0.095
9	3060	0.09
10	4020	0.10
11	3440	0.09
Mean	3474	0.0904

7 The statement that rattling increases the strength by about 25 per cent seems to be borne out by experiments. The increased strength is probably due to a removal of some of the internal stresses in the specimens and to the fact that the particles of iron, by the process of tumbling the bars together, are allowed to arrange themselves so that they are better able to resist stresses than they were before rattling.

8 Since the breaking load varies directly as the moment of inertia of the cross section of the specimen about the gravity axis, we have

Ig for the specimens $1\frac{1}{4}$ in. diameter $= \frac{1}{4}\,\pi r^4 = 0.7854 \times 0.625^4 = 0.12$
Ig for the specimens 1 in. square $= \frac{1}{12}\,bh^3 = \frac{1}{12} = 0.0833$

Then

$$\frac{0.1203}{0.0833} = 1.44$$

Making the comparison between the unrattled round specimens and the square ones, we have

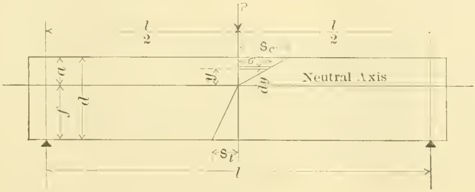
$$\frac{2805}{2335} = 1.2$$

Comparing the rattled round specimens with the square ones we have

$$\frac{3474}{2335} = 1.487.$$

Geo. M. Peek. The paper brings up a point which I have had in mind for some time, and which I have never seen explained in any of the text books on the strength of materials or any of the engineer's

hand books. The formula in Par. 15 is obviously not applicable to cast-iron beams, for the reason that it assumes that the neutral axis of a rectangular beam is in the center, which is true only when the beam is made of a material with equal tensile and compressive strengths.



2 In order that we may be able to construct a formula to be used in the design of a beam made of material whose crushing and tensile strengths are not equal, we must know the ratio between them. It may be reduced as follows, referring to Fig. 1, herewith:

Let M = bending moment $= \frac{Pl}{4}$ for load at center of span.

P = load at center.
l = length between supports.
S_c = compressive strength.
S_t = tensile strength.
b = breadth of beam.
d = depth of beam.
a = distance to extreme fiber on compression side.
f = distance to extreme fiber on tension side.
K = ratio compressive strength to tensile strength.

All dimensions are in inches.

3 We have the moment of resistance on the compression side

$$\int_0^a b\sigma y\,dy = \int_0^a bS_c\frac{y^2}{a}dy = \frac{ba^2}{3}S_c$$

and in like manner we find the moment of resistance on the tension side to be $\frac{bf^2}{3}S_t$. Since these two resistances are on opposite sides of the neutral axis they must be equal, or

$$\frac{ba^2}{3}S_c = \frac{bf^2}{3}S_t \text{ or } \frac{a^2}{f^2} = \frac{S_t}{S_c} = \frac{1}{K} \therefore f = a\sqrt{K}$$

4 Since the sum of these two resistances must be equal to the bending moment we have

$$M = \frac{b\,a^2}{3} S_c + \frac{bf^2}{3} S_t$$

Substituting KS_t or S_c

$$M = \frac{b\,S_t}{3} (K\,a^2 + f^2) = \frac{P\,l}{4}$$

$$P\,l = \frac{4}{3} b\,S_t\,(K\,a^2 + f^2) = \frac{8}{3} b\,S_t\,a^2\,K$$

$$d = a + f = a\,(1 + \sqrt{K})$$

$$\therefore a^2 = \frac{d^2}{(1 + \sqrt{K})^2}$$

Substituting again

$$P\,l = \frac{8}{3} b\,d^2 \frac{K}{(1 + \sqrt{K})^2} S_t$$

$$S_t = \frac{3}{8} \frac{(1 + \sqrt{K})^2}{8\,K} \frac{P\,l}{b\,d^2}$$

If we substitute 1.747 for K we get $S_t = \dfrac{P\,l}{1.155\,b\,d^2}$ or Clark's formula.

5 Taking the average compressive strength of cast iron as 112,000 lb. per sq. in., and the average tensile strength as 28,000, or $K = 4$, we have

$$S_t = \frac{P\,l}{1.185\,b\,d^2}$$

6 Applying this formula as Mr. Nagle does Clark's, in Par. 15, we have

$$\frac{2372 \times 1.185 \times 2 \times 1 \times 1}{24} = 2350$$

As will be seen, this formula gives results within 1.4 per cent of those obtained from the test.

A. A. Cary. It is unfortunate that the value of the structural study of metals and alloys, by use of the pyrometer and microscope, is

not more widely appreciated. I feel safe in saying that by such means all variations such as noted in Mr. Nagle's paper can be most satisfactorily accounted for. In iron and steel the fact is now generally recognized that metals identical in chemical composition may possess widely differing mechanical properties which are quickly recognized by microscopic examination.

2 Chemical analyses, as given in Table 1 of the paper, are undoubtedly of considerable value in the investigation of cast-iron; but without a physical examination our knowledge of the ability of the metal to withstand stresses and strains is very uncertain. Not only will investigations of this kind show us the cause of the variations noted in Mr. Nagle's paper, but they will give us the information needed to produce a metal of great uniformity.

PROF. T. M. PHETTEPLACE. It would be interesting to know whether a thorough sand-blasting would have any effect, as different results seemed to be obtained by cleaning off the skin of the material

THE AUTHOR. Since the paper was written I have had opportunity to examine some instructive records of eleven sets (of three each) of round test bars. The bars were $1\frac{1}{4}$ in. in diameter, rough, on 12-in. supports, the breaking loads being corrected for actual diameters. The deflections were not corrected.

BREAKING LOADS IN POUNDS. DEFLECTION FROM 0.12 IN. TO 0.15 IN.

1........	3276	3185	3044	4400	4005	2913	3276	3306	3382	3204	3268
2........	3367	3276	3162	3100	3913	3003	3185	3204	2976	3204	3124
3........	3276	3534	3255	3500	3640	3115	3026	2937	3003	2912	2812

2 The three bars in each set were cast in three separate molds, No. 1, or the upper line, being cast from the first pour of the ladle, No. 2 from the middle and No. 3 from the bottom. It will be observed that in eight of these eleven sets, the bar selected from the two nearest in agreement, came from the middle of the pour, and that all of the extreme variations were found in either the first or last pour. If we have only two bars they would differ as much as 22 per cent, while if we took the two out of three nearest in agreement, those two would not vary more than 2 per cent or 3 per cent.

3 I am very glad that Mr. Peek has taken up the mathematical solution of fitting a formula to the facts. Whether his demonstration or Clark's is the correct, or the better, one, I will not attempt to say,

but it is a pleasure to find that the two methods agree so well with the facts. I trust that this publicity will banish the old form of formula from the text books.

4 Professor Gregory has made an oversight in the dimensions of my bars. Being twice as wide as his, the deflections do not show very great variations: as $4 \times 0.09 = 0.36$ to 0.45, instead of $8 \times 0.09 = 0.72$ to 0.45.

5 I have had no experience with bars 1 in. by 1 in. by 12 in., but I think that 0.15 in. deflection would be difficult to realize in machinery castings.

THE BUCYRUS LOCOMOTIVE PILE DRIVER

By Walter Ferris, Published in The Journal for November 1909

ABSTRACT OF PAPER

This paper describes a new railway pile driver recently put on the market. The leading feature is a very powerful propelling apparatus and a large boiler, enabling it to act as a locomotive and haul its own train of tool cars, boarding cars, etc., over the road.

In order to transmit more than 250 h.p. to the axles of ordinary bogie trucks, which do not remain in line with the car body when passing curves, a special type of driving connection has been developed and is described in detail with drawings. The machine carries the pile driver apparatus at one end or the car, with power devices for raising the leaders and for swinging them to either side of the track as desired.

To enable the machine to drive piles at the other end when no railway turntable is at hand, a special turntable is attached to the under-side of the main car sills just above the track. This consists of hydraulic lifting apparatus and a large ball bearing upon which the entire pile driver, including trucks, is lifted clear of the track and turned end for end in from ten to fifteen minutes.

DISCUSSION

A. F. Robinson.[1] I feel very much pleased with the behavior of this driver as far as we have gone. I am especially pleased with the last three drivers, which are equipped with the extra high-speed gear. Our men find in handling this driver that it saves a good deal of time over the locomotive, especially in the short moves required in spotting the pile for driving and also the short run back to the end of a bridge to obtain piles.

2 As soon as this machine is thoroughly understood a great many will be used. This will be especially the case when we use reinforced-concrete piling more extensively.

L. J. Hotchkiss.[2] There are in use many antiquated pile drivers which are slow and difficult to handle. In some cases the leaders

[1] Bridge Engineer, Atchison, Topeka and Santa Fé Ry.

[2] Asst. Bridge Engineer, Chicago, Burlington & Quincy R. R., Chicago, Ill.

must be raised by means of a set of blocks attached to the track ahead of the driver, the fall line being carried to a spool on the engine. With such a machine ten minutes may be required to raise or lower the leaders. Where the work is not too far from the station, and there are no overhead obstructions, it may not be necessary to lower the leaders when running to the station. In many places, however, the leaders must be lowered every time the pile driver goes in, and raised again on coming out. On a busy single-track railroad this may cause much loss of time in the course of the day.

2 The time loss may not be merely that directly caused by slow handling of the machine. In many locations the movement of trains is such that there are several periods during the day when with a quickly operated driver there is just time between trains to run out, drive one or two piles and get in the clear again. With a driver operated as previously described this cannot be done, as so much time is required to handle the leaders that there is none left for driving piles. There are, however, drivers which do not have this objection but which must be handled by a locomotive. This is expensive in two ways. There is charged to the work of pile driving the cost of engine service, and the locomotive is kept out of regular train service. In times of heavy business the latter item is in itself one of considerable importance.

3 The self-propelling feature of the machine described by Mr. Ferris, its large boiler capacity and the arrangement for turning it, are its most prominent features. As stated by Mr. Ferris, the usual charge for a locomotive and crew is from \$20 to \$30 per day, \$25 being assumed as a fair average charge. The locomotive will furnish steam for the driver, making a fireman on the latter unnecessary. In the case of the self-propelling driver it is necessary to have a fireman, and as the machine is somewhat complicated, better men must be employed both as engineer and as fireman than would be needed ordinarily. For this reason the net saving by cutting out engine service probably will not exceed \$20 per day. It is not unusual to have from 600 to 800 piles to drive on one division in a single season. If we estimate that 20 piles a day are driven, and this number is well above the average, 30 days will be required to drive 600 piles. For this period the charge for engine service would amount to \$600, which is 5 per cent on an investment of \$12,000. It will thus be seen that the elimination of engine service in pile-driving work is a matter of no small importance.

4 A machine such as Mr. Ferris describes has sufficient power and

steaming capacity to handle its own train a considerable distance. Where a long haul is to be made the propelling mechanism is quickly thrown out of gear and the whole outfit put in a regular train. One of these pile drivers recently handled a train consisting of four bunk cars, a locomotive tender fully loaded with coal and water, one car containing 40 tons of coal, and a way car. This train was taken up a 1.4 per cent grade more than a mile long. A few days later this driver hauled 140 tons in addition to its own weight up the same hill at about 7 miles per hour. The steam gage showed 175 lb. pressure when the top of the hill was reached.

5 The conditions of railroad operation today require that all possible economies be made both in operation and construction. The locomotive pile driver of large capacity is a recent development and one which must still be regarded, to a certain extent, as an experiment. Experience so far, however, indicates that it is an economical machine, in that it dispenses with locomotive service and is quickly handled on all classes of work.

The Author. The railway pile driver is used for two general classes of work, construction and maintenance. For construction work, in most cases, almost any track machine which is capable of driving piles will answer the purpose fairly well, because in such work the machine, if fairly well fixed, is able to stand for considerable periods of time at one place, and efficiency as a pile driver is the leading object.

2 In maintenance work, however, which generally consists in repairs, such as strengthening the abutment of a bridge which is showing some signs of washing down, or especially in repairs after a washout, the mobility of the machine is the leading feature. To illustrate this point, I may say that the first machine of this design which we built was tried out at a bridge in California which was a mile and a half from the nearest railroad siding. I happened to be with that machine at the time, and during the forenoon we ran it out from the siding to the bridge we were repairing, and back into the siding again, seven times, to dodge passing trains. During this time twelve piles were driven, one or two at each trip.

3 The base price of this machine is $11,650 without the turntable and the steam hammer. As the turntable and steam hammer, and electric light plant and other extras are added, the total price may run to something about $14,000. This represents an increase of cost to the railroad, above what they have been accustomed to pay

for a pile driver, of $3,000 to $4,000 for each machine. The experiment in the case of this machine was quite as much in the line of commercial engineering as of mechanical engineering. When we built the first machine we were a good many thousand dollars behind, and somewhat doubtful if we would get it back. It looks now as if the machine would take very well. The operating department of the Southern Pacific, to which we recently furnished a machine, had previously charged the bridge department $45 a day for the use of a locomotive, which was dispensed with by the use of a machine capable of doing its own propelling work.

THE PITOT TUBE AS A STEAM METER

By George F. Gebhardt, Published in The Journal for Mid-November 1909

ABSTRACT OF PAPER

The application of a pitot tube system along the lines described in the paper is an accurate means of determining the *velocity* of steam at any point in a pipe, provided the values of the various influencing factors are known; and for straight lengths of piping with continuous flow, under these conditions, it is an accurate means of determining the *weight* of steam flowing.

Under average commercial conditions in which the pressure and quality of the steam fluctuate and an average value must be taken for the density of the self-adjusting water column, only approximate results can be obtained, the extent of error varying with the degree of fluctuation.

For velocities in excess of those corresponding to a 1½-in. water column (about 2000 ft. per min. for pressures over 70-lb. gage pressure), tests gave a maximum error of about 2 per cent for continuous flow in straight lengths of piping.

The coefficient of the tubes, as applied in Fig. 12, is practically unity and no calibration of the apparatus is necessary.

Further tests are necessary to show whether application, as in Fig. 13 and Fig. 14, gives reliable results.

DISCUSSION

Prof. W. B. Gregory. The pitot tube was invented in 1730. An account of the tube and the manner in which it was invented may be found in Histoire de l'Academie des Sciences for 1732. This paper by Pitot is of considerable interest. Some of its accompanying drawings are reproduced in a paper which I presented before the Society on The Pitot Tube, published in the Transactions, Vol. XXV. The statement of Mr. Gebhardt that the tube was first used in 1837 is evidently a misprint.

2 The author has apparently developed a practical instrument of real value. However, it seems to the writer that the device for determining aspiration effects can not be relied upon to make determinations of any value. Fig. 6 shows a special fitting, which, after pipes are screwed into the two ends, will be anything but an ideal fitting to

give correct static pressures. Most of the trouble in the past has been on the static side. The fitting shown amounts to an enlargement of the pipe beyond the end of the entering pipe and then a contraction where the steam enters the outgoing pipe. Serious eddying must result and it does not seem at all likely that the slots *ss* are long enough to neutralize the effect of the eddying and the change of section. Even if they do correct these errors it does not follow that *B* is located where it will give the correct mean pressure in the special fitting. The change of section and consequent eddying may change the pressure along the special fitting so that the pressure shown at *B* is not the true mean pressure.

3 I would like to ask Professor Gebhardt if he has used static openings about 1/16 in. in diameter drilled at right angles to the axis of the pipe? Extensive experience with the pitot tube as a device for measuring the velocity of water has taught me to avoid irregularities in a pipe, due to special fittings or other causes, when the static pressure is taken from the walls of the pipe. An unobstructed length of straight pipe is absolutely essential to accurate work.

4 The desirability of finding the correct static pressure is apparent as it seems probable that one constant would apply to reduce velocity at the center to mean velocity, in any and all sizes of pipe. The experimental determination of the correct angles for the static nozzle, as shown in Fig. 5, would then be avoided.

Walter Ferris. The remarks of Professor Gregory in regard to the special fitting for finding the effect of aspiration reminded me forcibly of an experience a few years ago with both a venturi meter and a pitot tube for measuring water. Perhaps the conclusions at which I arrived at that time may be suggestive, although possibly not of direct application in the case of a steam meter.

2 Until quite recently, that is, within a few years, I think it has been assumed that it was necessary, in the use of the pitot tube, to have a static tube close to the dynamic tube, or at least at the same distance from the walls of the conduit. I believe that William Monroe White, six or seven years ago, made some experiments demonstrating that the velocity head taken from the impact side of a pitot tube is correct, whatever the shape of the nozzle, so long as it is a surface of revolution. Thus the nozzle may be either cylindrical, or a converging or diverging cone, and the dynamic head will be correctly indicated, any variations in the coefficient of the pitot instrument as a whole being due to the shape or location of the static opening.

3 In the venturi meter, we find that the static pressure is always taken from the walls of the conduit, where the velocity may not be over half the maximum velocity, and yet the results from the venturi meter are invariably correct to within one per cent, if conditions are favorable. Therefore a dynamic nozzle, which is a surface of revolution, combined with a static nozzle terminating in the wall of the conduit (as in the venturi meter) should together form a pitot instrument which is correct to the formula, and needs no calibration. This seems to indicate that for a pitot instrument to measure the flow of water it is not necessary to take the static head and the dynamic head in regions of the same velocity, and that the true average static pressure will be indicated through intervening velocities, and correctly registered, even when the piezometer is located in a region of low velocity. From this I infer that in this steam meter sufficiently small static openings in the true smooth wall will probably give correct results as they do in the water meter, although I have no experimental data with which to confirm this opinion.

A. R. Dodge. I would like to take exception to a statement in Par. 6: "On account of the great density of mercury and the variation in height of the condensed vapor above the mercury, this application of the pitot tube has very little value scientifically or commercially." The General Electric Company has developed a steam meter, both of the indicating and recording types and has built several hundred of these meters using mercury and condensed vapor above the mercury. This condensed vapor automatically remains at a constant head.

2 Recently three recording meters, selected at random out of a lot of fifty, showed a maximum error of less than two per cent. Ninety per cent of the readings were within one per cent on the three meters, which had an automatic pressure correction and also a temperature correction. These meters can be used on any size of pipe, from 2 in. up to 36 in., the 36-in. pipe, of course, being for atmospheric conditions of steam. These steam meters we have found to be valuable in improving the consumption of steam in our various plants.

3 We have also experimented with several of the types described in this paper in which mercury is not used and have found them excellent in many respects, but the use of mercury is not at all objectionable.

The Author. Prof. W. B. Gregory is correct in his statement concerning the defects in the apparatus for determining aspiration

as illustrated in Fig. 6. This drawing refers to an old discarded fitting and was published through an oversight. The apparatus used in connection with the tests recorded in the paper is the same in principle but differs in the details of construction. The inner surface of the fitting is of the same degree of smoothness as that of the pipe. This inner diameter of the chamber corresponds to that of the pipe. The ends of the pipes are threaded and finished in such a way as to fit snugly against the threaded end of the fitting, forming a practically continuous tube of uniform diameter. The slots are 10 in. long and ¼ in. in thickness. Careful measurements with searching tubes and delicately balanced differential manometer failed to show eddies of appreciable magnitude.

2 Static openings, about one-sixteenth of an inch in diameter, drilled at right angles to the axis of the pipe, showed no aspiration effects at velocities up to 15,000 ft. per min. (the maximum obtained during the tests) but are unsuitable for the appliances described. It is the author's intention to develop a simple meter which can be constructed of standard fittings and which may be attached by tapping the pipe in the ordinary way. Such an application necessitates the projection of the static nozzle beyond the inner surface of the pipe, an arrangement which causes serious aspiration. With a standard ½-in. nipple projecting ½-in. beyond the inner surface of a 3-in. pipe an aspiration effect corresponding to 10 in. of water was noted at a velocity of 12,000 ft. min. (pressure 100 lb. gage). At a velocity of 6000 ft. per min. the aspiration amounted to 1½-in. of water. It was for the purpose of neutralizing this aspiration that the static nozzle was cut at an angle, as indicated in Fig. 5.

3 Mr. Ferris' remarks are in accordance with experiments conducted by the author, but, as stated above, a static opening terminating with the inner wall of the conduit is not applicable to the instruments in question. Fig. 1 illustrates such a static opening, but in the actual construction the nozzle projected ½ in. beyond the inner surface.

4 Mr. Dodge's experiments with the use of mercury as an indicating medium are of considerable interest, in that they show the development of a practicable and accurate steam meter which is little known to the general engineering public. It would be of great interest if Mr. Dodge would describe the instrument used at the works of the General Electric Company and give some of the test results.

GENERAL NOTES

AMERICAN SOCIETY OF CIVIL ENGINEERS

At the meeting of the American Society of Civil Engineers, February 2, two papers were presented for discussion: Underpinning the Cambridge Building, New York City, by T. Kennard Thomson, Mem.Am.Soc.M.E., and Building Agreements, by Wm. B. Bamford. The papers presented at the meeting of February 16 were: The Effect of Alkali on Concrete, by Geo. Gray Anderson; and Precarious Expedients in Engineering Practice, by John Hawkesworth. On March 2, a paper entitled The Improved Water and Sewage Works of Columbus, Ohio, will be presented by John H. Gregory.

AMERICAN INSTITUTE OF MINING ENGINEERS

The Society takes pleasure in announcing the invitation extended to the members of this Society by the American Institute of Mining Engineers, to attend their Convention at Pittsburg, Pa., beginning Tuesday evening, March 1, 1910. The members of this Society will be welcome at the professional sessions and at such of the excursions as may be undertaken, where the number does not exceed the available facilities.

The Institute headquarters will be at the Hotel Schenley, where a bureau of information will be maintained, and the sessions will be held at the Carnegie Library, opposite the hotel. The Secretary of the Local Committee is Harrison W. Craver, Carnegie Library, Pittsburg, to whom should be addressed all inquiries concerning local matters and arrangements of the meetings.

There will be an excursion to the steel plant at Homestead, which will occupy one day, and an afternoon will be devoted to a visit to the testing station of the United States Geological Survey, where special tests will be made showing the effect of various explosives on mine gas, etc., also some tests on reinforced concrete beams. Arrangements will also be made for a visit to a coal mine and to various manu-

facturing plants. Details of the sessions and excursions will be given in the program furnished to each guest on registration at the headquarters.

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

The Society of Naval Architects and Marine Engineers is arranging for representatives to attend the fiftieth anniversary of the founding of the Institution of Naval Architects, to be held in London, July 5, 1910, and to be made the occasion of an international congress.

Papers and subjects connected with naval architecture and marine engineering will be read and discussed and the attendance of a large number of distinguished naval architects, shipbuilders and marine engineers from all parts of the world is anticipated.

INTERNATIONAL CONGRESS OF MINING, METALLURGY, APPLIED MECHANICS AND PRACTICAL GEOLOGY

An invitation to the International Congress of Mining, Metallurgy, Applied Mechanics and Practical Geology, to be convened at Dusseldorf, June 20–23, 1910, has been extended to the members of The American Society of Mechanical Engineers. This notice is published for the benefit of individual members who may be able to attend, as the Society is unable to accept as a body the invitation to be present.

NATIONAL CIVIC FEDERATION

The following Honorary Vice-Presidents were appointed to represent the Society at the conference of the National Civic Federation in Washington, D. C., January 17–19, 1910: Jesse M. Smith, Past-President, Chas. Kirchhoff, A. W. Burchard, E. G. Spilsbury, F. M. Whyte and Wm. H. Wiley.

The conference was called to consider uniform state legislation and has formed itself into a permanent organization for the purpose with Alton B. Parker as President. Annual conferences will probably be called. The conference endorsed the conservation of American forests and referred the matter of uniform state laws, providing for right methods of forests taxation and for the effective protection of forests from fire, to the Commission on Uniform State Laws. The regulation of water power by state and federal control was also recommended. A number of other resolutions were passed

upon subjects of national importance, urging uniformity in laws relating to taxation, insurance, child labor, public accounting, legal procedure, etc.

NEW YORK ELECTRICAL SOCIETY

On January 27, 1910, Prof. W. S. Franklin of Lehigh University gave a lecture before the New York Electrical Society, 29 West 39th Street, New York, on The Practical Applications of the Gyrostat. Professor Franklin discussed the physical action and the establishment of the kinematical diagram of the gyroscope, the gyrostatic action of the flywheel of the automobile engine and on shipboard, as well as of the boomerang, Schlick's device for the prevention of rolling of ships at sea, and the Brennan monorail car.

ENGINEERS CLUB OF PHILADELPHIA

The thirty-first annual meeting of the Engineers Club of Philadelphia was called to order by the President Dallett, February 5, 1910, with 129 members and visitors in attendance. An address on Recent Developments in Engineering Practice was made by President Dallett. Following a report of the tellers the following were declared elected as officers of the club: Wm. Easby, Jr., president; Chas. Hewitt, vice-president; W. Purves Taylor, secretary; E. J. Kerrick, treasurer.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The regular monthly meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineering Societies Building, on Friday, February 11, 1910. W. Lee Campbell of the Automatic Electric Company of Chicago presented a paper entitled, A Modern Automatic Telephone Apparatus. A complete installation connected up for service was on exhibition.

At the annual dinner of the Institute, held at the Hotel Astor on Thursday evening, February 24, Dr. Elihu Thomson, to whom has been awarded the first Edison Medal, was the guest of honor. The following were the speakers of the evening: Dr. John H. Finley, president, College of the City of New York, Education and Invention; Samuel Insull, president Edison Medal Association, Meritorious Achievement in Electrical Engineering; Lewis Buckley Stillwell,

president, A.I.E.E., The Edison Medal, with response by Dr. Thomson. Mr. T. C. Martin acted as toastmaster.

WESTERN SOCIETY OF ENGINEERS

The Chanute medals of the Western Society of Engineers, founded by Dr. Octave Chanute, have been awarded for 1908 to Horace E. Horton, Prof. A. N. Talbot and Morgan Brooks, Mem.Am.Soc. M.E. Mr. Horton's paper was Compression Bridge Members, Professor Talbot's a report of Tests of Reinforced Concrete and Cast-Iron Pipe, and Professor Brooks' was Alternators in Parallel.

SHEFFIELD SCIENTIFIC SCHOOL NEW LABORATORY OF MECHANICAL ENGINEERING

A gift of $250,000 has recently been received by the Sheffield Scientific School of Yale University, from George G. and William S. Mason, graduates in the class of 1888, to be expended for the construction and equipment of a new mechanical engineering laboratory, on a site to be provided by the Board of Trustees. The laboratory will be located on Hillhouse Avenue, will be four stories in height, and will contain approximately 50,000 sq. ft. of floor area and 880,000 cu. ft. of space. The entire equipment will be new and will consist of the most modern appliances for assisting the student in studying the fundamental principles of applied science closely related to mechanical engineering, such as the strength of materials, the combustion of fuel in furnaces and in internal-combustion engines, the making of steam in boilers of different types, the using of saturated and superheated steam in engines or steam turbines, the artificial production of cold, the production, transmission and use of compressed air, the pumping of water, the transmission of power, and the problems of heating and ventilation. It is expected that this laboratory will furnish a field for research work in engineering science, as well as undergraduate and graduate instruction. It is expected that the building will be completed and equipped by June 1911.

COLUMBIA UNIVERSITY COURSE IN WORKS MANAGEMENT

A series of twenty lectures by non-resident lecturers is being conducted in the Department of Mechanical Engineering, Columbia

University, constituting a course in Works Management. Lectures are given on Thursdays and Mondays of each week, at 4.10 p.m., beginning February 10 and closing May 14, in Room 301 Engineering. The course consists, in the following order, of six lectures by Charles B. Going, managing editor of the Engineering Magazine; four by Charles U. Carpenter, Mem.Am.Soc.M.E., president of the Herring-Hall-Marvin Safe Company; two by H. L. Gantt, Mem.Am. Soc. M.E., one by Walter M. McFarland, Mem.Am.Soc.M.E., vice-president of the Westinghouse Electric & Mfg. Co.; three by Harrington Emerson, Mem.Am.Soc.M.E.; three by Richard T. Lingley, C.P.A., treasurer of the American Real Estate Company; and a concluding lecture by Edwin J. Prindle, member of the New York Bar.

STEVENS INSTITUTE ALUMNI DINNER

The ninth annual dinner of the Stevens Institute Alumni Association was held in the Hotel Astor on February 12. Among the speakers were Dr. Alex. C. Humphreys, Mem.Am.Soc.M.E., President of the Institute, Dr. H. S. Pritchett of the Carnegie Foundation, and Col. G. B. M. Harvey of Harper's Weekly.

PERSONAL

A. Bement has been elected second vice-president of the Western Society of Engineers. Mr. Bement presented a paper on the Chicago Harbor Problem before this Society at their meeting of February 16.

Morgan Brooks has been awarded one of the Chanute medals of the Western Society of Engineers for 1908. His paper was on Alternators in Parallel.

C. P. Chester, formerly superintendent of the Morenci Water Company, Morenci, Ariz., has opened a consulting engineering office in El Paso, Texas.

C. W. Comstock has been appointed president of the Comstock-Wellman Bronze Company, Cleveland, O.

Thomas F. Cooke has formed a partnership for consulting engineering with Richard L. Webb, under the name of Webb & Cooke, with an office in Buffalo, N. Y. The firm will make a specialty of power costs.

Fred H. Daniels has been decorated with the Cross of Knighthood of the Northern Star by King Gustav of Sweden in token of his work as an engineer and for courtesies extended to Swedish engineers in this country.

Arthur Falkenau, formerly president of the Falkenau-Sinclair Machine Company, Philadelphia, Pa., has become associated with George K. Hooper, New York.

J. Edwin Fulweiler has become associated with the United Gas Improvement Company of Philadelphia. He was until recently in the engineering department of the Otto Gas Works, Philadelphia, Pa.

W. B. Gregory has been elected president of the Louisiana Engineering Society.

Edwin J. Haddock, formerly chief engineer of the chain department of the Jeffrey Manufacturing Company, has given up his office in Columbus, O., to become mechanical and structural engineer of the Tennessee Coal, Iron & R. R. Co., in the coal mining department, with office at Birmingham, Ala.

F. A. Hall, manager of the chain block and hoist department of the Yale & Towne Mfg. Co., New York, has resigned that position to become vice-president and treasurer of the Cameron Engineering Company, of Brooklyn, N. Y.

F. A. Halsey sailed January 20 on the steamship Arabic for a cruise to the Mediterranean and the Orient. Mr. Halsey expects to be gone about three months and before returning intends to visit some of the important industrial centers of Europe.

Walter Laidlaw, formerly vice-president and general manager of the Snow Steam Pump Works, Buffalo, N. Y., has become identified with the International Steam Pump Company, New York.

Wm. Y. Lewis, formerly manager of the erecting department of the International Steam Pump Company, has established an office of his own at 49, Queen Victoria St., London, E. C., as advisory engineer.

W. A. McFarland, for many years superintendent of the Washington, D. C., water works, has opened an office in the Washington Loan and Trust building, as consulting engineer in matters relating to water works and power plants. He will be associated in a consulting capacity with the engineering firm of Beale & Meigs, which carries on a general engineering practice.

C. J. Morrison, until recently connected with the Emerson Company, has opened an office in New York for efficiency engineering work.

Leslie Moulthrop has received his discharge from the Superior Court as receiver of the Dwight Slate Machine Company, Hartford, Conn., having paid the general creditors in full. The company will be conducted under the same name by a new organization.

Albert Spies has retired from the editorship of the Electrical Record to become the managing director of Foundry News, a new illustrated monthly publication devoted to the foundry arts.

George F. Starbuck, formerly draftsman of the mechanical department of the N. Y., N. H. & H. R. R., New Haven, Conn., has become associated with the Boston Elevated Railway, Boston, Mass., as draftsman in the department of rolling stock and shops.

Cecil H. Taylor has been appointed chief engineer of the Hudson Motor Car Company, Detroit, Mich. He was formerly designing engineer of the Chalmers Motor Car Company, Detroit, Mich.

Charles E. Waddell, formerly consulting engineer, Biltmore Estate, Biltmore, N. C., has established offices for general engineering practice in Asheville, N. C.

Gilbert S. Walker, formerly located at Wheeling, W. Va., has become connected with the Isthmian Canal Commission, Washington, D. C.

James T. Wallis, superintendent of motive power on the Erie division of the Pennsylvania R. R. and the Northern Central has been appointed acting superintendent of the West Jersey & Seashore, R. R., also of the Philadelphia and Camden Ferry, with office at Camden, N. J.

C. H. Zehnder has been elected vice-president of the Empire Steel & Iron Co.

W. H. Zimmerman, formerly manager of the Michigan Power Company, Lansing, Mich., has been retained by the Michigan Railroad Commission as consulting engineer.

CURRENT BOOKS

ENGINEERS' AND FIREMEN'S LICENSE LAW; BOILER INSPECTION LAW; RULES FORMULATED BY THE BOARD OF BOILER RULES. Pamphlet issued by the Commonwealth of Massachusetts, 1909. *Wright & Potter Printing Co., Boston, Mass., 1909.* Viii + 67 pp., illustrated.

Contents: Engineers' and Firemen's License Law; Boiler Inspection Law; Rules formulated by the Board of Boiler Rules; Recommendations made by the Board of Boiler Rules; Index to Rules.

FOWLER'S ELECTRICAL ENGINEER'S POCKET BOOK. Edited by Wm. H. Fowler. 10th annual edition. *Scientific Pub. Co., Manchester, England, 1910.* Cloth, pocket book size, 575 pp., illustrated. Price 1/6 net.

Contents: Miscellaneous Tables, etc.; Wire Tables; Magnetism and Magnetic Data; Conductors and Insulating Materials; Electric Lighting and Wiring; Comparison and Measurement of Resistances; Electrical Measuring Instruments; Electricity of Meters; Primary and Secondary Batteries; Dynamos and Motors; Alternate Electric Currents; Alternators; Transformers; Alternate Current Motors; Switch boards, Circuit Breakers and Lightning Arresters; Electrical Power Transmission and Distribution; Rotary Converters; Electric Traction; Rules and Regulations.

FOWLER'S MECHANICAL ENGINEER'S POCKET BOOK. Edited by Wm. H. Fowler. 12th annual edition. *Scientific Pub. Co., Manchester, England, 1910.* Cloth, pocket book size, 653 pp., illustrated. Price 1/6 net.

Contents: Miscellaneous Tables and Formulæ; Steam Boilers and Fittings; Fuels and Combustion Steam Engines; Steam Turbines; Locomotives; Steam Tables; Valves and Valve Gear; Gas Engines; Gases used in Gas Engines; Oil Engines; Hydraulics; Pumps and Pumping Arrangements; Gearing and Lubrication; Hoisting and Lifting Machinery; Mining Machinery and Appliances; Metallurgy of Iron and Steel; Strength of Metals and Alloys; Beams and Pillars; Springs; Chemistry; Ventilation and Heating.

SLIDE RULE. AN ELEMENTARY TREATISE. By J. J. Clark,M..E. *Technical Supply Co., New York, 1909.* Cloth, 6 vo., 62 pp., with diagrams. Price, 45 cents.

Contents: Introduction; the Mannheim Slide Rule.

SMOLEY'S TABLES. Parallel Tables of Logarithms and Squares, Angles and Logarithmic Functions, with complete set of Five-Decimal Logarithmic-Trigonometric Tables. By Constantine Smoley, C.E. 5th edition, revised. *Engineering News Pub. Co., New York, 1908.* Morocco, pocket book size. Price, $3.50.

Contents: Parallel Tables of Logs and Squares; Table of Bevels; Multiplication Table; Explanation and Examples; Constants; Decimal Equivalent; Logarithms of Numbers; Log. Functions by 10″; Angles Between 0° and 1° Log. Functions by 1′; Natural Functions; Formulæ; Constants; Decimal Equivalents.

TIME AND ITS MEASUREMENT. Ry James Arthur. Reprinted from Popular Mechanics Magazine, Chicago, 1909. Cloth, 12 vol., 64 pp., illustrated.

Contents: Historic Outline; Japanese Clocks; Modern Clocks; Astronomical Foundation of Time.

FOWLER'S MECHANICS' AND MACHINISTS' POCKET BOOK AND DIARY, 1910. Edited by Wm. H. Fowler. 2d edition. *Scientific Pub. Co., Manchester, England, 1910.* Cloth, pocket book size, 448 pp. Price 6d.

Contents: Handy References and Tables; Mensuration, Geometry, and Trigonometry; Uses of Logarithms and Antilogarithms; Materials Used in Machine Construction; Machine Tool Design; Proportions of Machine Tool Parts; Metal Cutting Tools; High Speed Tool Steels; Drilling and Boring Metal; Screw Threads, Screw Cutting, and Taper Turning; Emery and Emery Wheels; Shop Practice; Wheel Gearing; Belt and Rope Driving, Shafting; Lifting Ropes and Chains.

KEMPTHORNE'S RAILWAY STORES PRICE BOOK. Being a Handbook of Prices of Stores and Material used in the Construction and Maintenance of Railways. By William Oke Kempthorne. *E.&F.N.Spon, Ltd., London, England, 1909.* Cloth, 8 vo., 487 pp. Price, $4.

THE CIVIL ENGINEER'S POCKET BOOK. By John C. Trautwine. 19th edition. *New York, John Wiley & Sons, 1909.* Morocco, pocket-book size, pp. xxxii + 1257 + 26. Price, $5.

Contents: Mathematics; Natural Phenomena; Mechanics, Force in Rigid Bodies; Strength of Materials; Hydrostatic Hydraulics; Constructions, etc.; Water Supply; Traction, Animal Power; Suspension Bridges; Rivets and Riveting; Railroads; Materials; Price List, etc.; Bibliography; Logarithmic Sines, etc.; Concrete.

LARGE GAS ENGINES. By Percy R. Allen. Reprinted from Cassier's Magazine, 1909. Cloth, 61 pp.

Contents: The Four-Cycle Engine—British and Continental Practice; The Four-Cycle Engine—American Practice; Two-Cycle Engines.

ENERGY. Work, Heat and Transformations. By Sidney A. Reeve, M.E. *New York, McGraw-Hill Publishing Co., 1909.* Cloth, 8 vo., 238 pp. Price, $2.

Contents: Mechanical Energy; Free and Vibratory Energies; The Mean Energetic Condition and the Energy-fund; The Two Factors of Dimensions of Energy; The Extreme or Critical Energetic Conditions; The General Nature of Mechanical Energy; What is Heat?; The Thermal Diagram; Mechanical Concepts of Thermal Phenomena, Pressure and Volume; The Two Basic Thermal Processes: Heat-transfer and Work-performance; Mechanical Concepts of Thermal Phenomena, Temperature and Entropy; The Energetic Cycle; Reversed and Irregular Cycles; Thermal Equilibrium; Transformations and Conservations.

LINSEED OIL AND OTHER SEED OILS. An Industrial Manual. By Wm. D. Ennis, M.E. *New York, D.Van Nostrand Co., 1909.* Cloth, 8 vo., xiv + 316 pp. Price, $4.

Contents: Introductory; The Handling of Seed and the Disposition of Its Impurities; Grinding; Tempering the Ground Seed and Molding the Press Cake; Pressing and Trimming the Cakes; Hydraulic Operative Equipment; The Treatment of the Oil from the Press to the Consumer; Preparation of the Cake for the Market; Oil Yield and Output; Shrinkage in Production; Cost of Production; Operation and Equipment of Typical Mills; Other Methods of Manufacturers; The Seed Crop; The Seed Trade; Chemical Characteristics of Linseed Oil; Boiled Oil; Refined and Special Oils; The Linseed Oil Market; The Feeding of Oil Cake; Miscellaneous Seed Oils; The Cotton-Seed Industry.

HENLEY'S ENCYCLOPEDIA OF PRACTICAL ENGINEERING AND ALLIED TRADES. A Practical and Indispensable Work of Reference for the Mechanical Engineer, Designer, Draftsman, Shop Superintendent, Foreman and Machinist. Edited by Joseph G. Horner, A.M.I.Mech.E. *New York, The Norman W. Henley Pub. Co., 1909.* Vol. IX, SPE-Z, 240 pp., Illustrated. Price, $6.

THE GAS ENGINE. By Cecil P. Poole. *Hill Pub. Co., New York, 1909.* Cloth, 8 vo., 6 + 97 pp., illustrated. Price, $1.

Contents: Elementary Principles; Pressures and Temperatures; Cooling and Heat Loss; Valves and Valve Gear; Ignition; Mixing Liquid Fuel with Air; Methods of Governing; Some Considerations of Design; Care and Management of Engines; Pressure, Temperature and Output Calculations.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A.I.E.E. and A.I.M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

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Association of Transportation and Car Accounting Officers. *Proceedings.* December 1909. *Chattanooga, 1909.*

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Boston, Finance Commission. Report. Vol. 4. *Boston, 1909.* Gift of Samuel Whinery.

Commercial Deductions from Comparisons of Gasoline and Alcohol Tests on Internal-Combustion Engines. (Bulletin 392, U. S. Geol. Survey.) By R. M. Strong. *Washington, 1909.*

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Comparative Tests of Run-of-Mine and Briquetted Coal on the Torpedo Boat Biddle. (Bulletin 403, U. S. Geol. Survey.) By W. T. Ray and H. Kreisinger. *Washington, 1909.*

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Devonian Fauna of the Ouray Limestone. (Bulletin 391, U. S. Geol. Survey.) By E. M. Kindle. *Washington, 1909.*

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Equitable Charges for Tramway Supply. By H. E. Yerbury. (Institution of Electrical Engineers, 1909.) Gift of C. W. Rice.

Geological Features of the Country Lying along the Route of the Proposed Transcontinental Railway in Western Australia. (Bulletin 37, Western Australia Geol. Survey.) By C. G. Gibson. *Perth, 1909.*

GEOLOGY AND UNDERGROUND WATERS OF SOUTH DAKOTA. (Water Supply Paper No. 227, U. S. Geol. Survey.) By N. H. Darton. *Washington, 1909.*

GEOLOGY AND WATER RESOURCES OF THE NORTHERN PORTION OF THE BLACK HILLS AND ADJOINING REGIONS IN SOUTH DAKOTA AND WYOMING. (Professional Paper No. 65, U. S. Geol. Survey.) By N. H. Darton. *Washington, 1909.*

GEOLOGY OF THE LEWISTOWN COAL FIELD, MONTANA. (Bulletin 390, U. S. Geol. Survey.) By W. R. Calvert. *Washington, 1909.*

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HOW TO MAKE IMPROVEMENT THINNINGS IN MASSACHUSETTS WOODLANDS. By H. O. Cook. *Boston, 1910.* Gift of Massachusetts State Forester.

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MACHINE BUILDING FOR PROFIT AND THE HARTNESS FLAT TURRET LATHE. By James Hartness. *Springfield, Vt., 1909.*

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MANZANO GROUP OF THE RIO GRANDE VALLEY, NEW MEXICO. (Bulletin 389, U. S. Geol. Survey.) By W. T. Lee and G. H. Girty. *Washington, 1909.*

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NATIONAL ELECTRIC LIGHT ASSOCIATION. (Bulletin, Vol. 3. No. 6.) *New York, 1910.* Gift of C. W. Rice.

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NEW YORK STATE MUSEUM. 62d Annual Report. Vol. 2-4. *Albany, 1909.*

NON-MAGNETIC GAS ENGINE OF THE CARNEGIE. By J. Craig, Jr. From Terrestrial Magnetism, September, 1909.

NOTES ON SOME MINING DISTRICTS IN HUMBOLDT COUNTY, NEVADA. (Bulletin 414, U. S. Geol. Survey.) By F. L. Ransome. *Washington, 1909.*

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PLEISTOCENE GEOLOGY OF THE LEADVILLE QUADRANGLE, COLORADO. (Bulletin 386, U. S. Geol. Survey.) By S. R. Capps. Jr. *Washington, 1909.*

PRIMER ON EXPLOSIVES FOR COAL MINERS. (Bulletin 423, U. S. Geol. Survey.) By C. E. Munroe and C. Hall. *Washington, 1909.*

Radioactivity of the Thermal Waters of Yellowstone National Park. (Bulletin 395, U. S. Geol. Survey.) By H. Schlundt and R. B. Moore. *Washington, 1909.*

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Results of Spirit Leveling in West Virginia. 1896-1908, inclusive. (Bulletin 399, U. S. Geol. Survey.) By S. S. Gannett and D. H. Baldwin. *Washington, 1909.*

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Sydney University Engineering Society, New South Wales. *Proceedings.* Vol. 13, 1908. *Sydney, 1908.*

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EXCHANGES

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James Beggs & Co., *New York.* Feed water filtration, 32 pp.

Commercial Cable Co., *New York.* Silver anniversary souvenir, 36 pp.

Cummings Filter Co., *Philadelphia, Pa.* Water filters, 48 pp.

General Electric Co., *Schenectady, N. Y.* Bulletin 4679-A, Type DLC, commutating pole motors, 8 pp.; Bulletin 4684, Luminous arc headlight, 3 pp.; Bulletin 4706, Curve-drawing ammeter and voltmeter, 4 pp.; Bulletin 4707, Gasolene-Electric generating sets for lighting and power, 24 pp.; Bulletin 4708, Thomson direct current test meter, 4 pp.; Bulletin 4709, Portable instruments, 10 pp.; Bulletin 4713, Type F, forms K-2 and K-4 oil break switches, 7 pp.

Goldschmidt Thermit Co., *New York.* Reactions, Vol. 2, No. 4, 20 pp.

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Jeffrey Mfg. Co., *Columbus, O.* Catalogue 69 B. Revolving, stone and gravel bell shaped, panel and tipple screens, 24 pp.; Bulletin 17, Electric mine locomotives, 68 pp.

Lamson Consolidated Store Service Co., *Boston, Mass.* Small hand and power operated elevators, dumb-waiters and automatic conveyors, 24 pp.

Murray Iron Works Co., *Burlington, Ia.* Corliss engines, 80 pp.

Niles-Bement-Pond Co., *New York.* LeBlond milling machines, 42 pp.

North Western Expanded Metal Co., *Chicago, Ill.* Expanded metal for sidewalks, culverts, slab bridges, 24 pp.

Oneida Steel Pulley Co., *Oneida, N. Y.* Catalogue of steel and wood pulleys, 48 pp.

Pierce Motor Co., *Racine, Wis.* Pierce-Racine model K, 30 h.p. motor car, 16 pp.

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Pratt & Whitney Co., *Hartford, Conn.* Vertical surface grinder, 24 pp.

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Schoen-Jackson Co., *Media, Pa.* Flexible metal tubing and connections for pressures up to 4000 pounds, 16 pp.

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Storrs Mica Co., *Owego, N. Y.* "Never Break" mica chimneys and globes, 20 pp.

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POCKET COMPANION CONTAINING USEFUL INFORMATION AND TABLES APPERTAINING TO THE USE OF STEEL. 1903.

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STEEL MINE TIMBERS, DATA AND TABLES FOR THE USE OF MINING ENGINEERS, 46 pp.

STEEL SHEET PILING, 16 pp.

SCHOEN STEEL WHEELS. No. 1, 46 pp.

SCHOEN STEEL WHEELS, DESIGNS AND SPECIFICATIONS, 46 pp.

CARNEGIE SPECIAL WELDING STEEL, CARNEGIE SPECIAL THREADING STEEL, 40 pp.

CARNEGIE STEEL CROSS TIE AND DUQUESNE RAIL JOINT, 61 pp.

STEEL SHEET PILING. Types of construction and examples of installation, 64 pp.

STEEL MINE TIMBERS. Types of construction and examples of installation, 30 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

010 Assistant superintendent of factory manufacturing a line of small interchangeable parts in large quantities; man with technical training preferred. Must be experienced in shop management. Wanted May 1. Location, Philadelphia, Pa.

011 Wanted—Competent mechanical draftsman, preferably one who has had experience in coal mine equipment. Give full particulars, including salary required. Location, Birmingham, Ala.

012 Wanted—Thoroughly practical and energetic young man for experimental and testing department of large corporation. Must be technical graduate of three or four years standing. Principal work consists of engine and boiler testing, as well as all matters pertaining to power, exclusive of electric. Excellent chance for right man to become assistant.

013 Opening for three engineer-salesmen between twenty-five and thirty-five years of age, for selling gas and oil engines in and around New York City. Men of experience in selling are preferred. Applicant must of course be able to give the best of references.

014 Wanted—Ice-making and refrigerating machinery salesmen; experienced men preferred. Applicants should be between thirty and forty years of age.

MEN AVAILABLE

25 Technical graduate, Junior Member, several years' experience in engineering work and as sales engineer with manufacturers of internal combustion engines. Considerable traveling experience. Location of minor importance, opportunities all-important.

26 Member, at present superintendent in large machine shop, where he has been for several years, would like a change of locality; 19 years' experience in manufacture of steam engines, steam turbines, and machine tools. Capable of filling first-class position.

27 Technical graduate, experienced in varied lines of industry, has held executive positions of responsibility; desires to become associated in position of trust with good manufacturing concern, preferably located in the East or Middle West. Best of references.

28 Associate wishes position as general manager, assistant, sales manager or salesman. Good executive ability, twenty years' experience with machine-tool manufacturing company, and as appraiser and receiver.

29 Member having extensive executive and mechanical experience desires to secure a position in greater New York or vicinity as superintendent or factory manager. Light, medium or heavy lines; large experience in intricate automatic and precision mechanisms as well as modern manufacturing methods and systems.

30 Member, technical graduate; 15 years' experience in power plant equipment and rolling mill machinery with well-known firm, last five years in engineering sales work, desires responsible position in the commercial end of a metal trade business, or as branch manager on commission basis. Experience in this country and abroad.

31 Member, graduate mechanical engineer, 18 years' experience in the States, England and France, as chief draftsman, general superintendent, selling and buying engineer, desires responsible position. Good executive, specialty automatic, hydraulic and conveying machinery. Best references.

32 Graduate in mechanical engineering, Massachusetts Institute of Technology, with experience including shop, inspection and drafting work, desires position in engineer's office as assistant to superintendent, or similar position. Minimum salary expected at start, $900 per year.

33 Mechanical engineer, Associate Member; 8 years of expert work in the reduction of power costs in industrial plants. Present practice as consulting engineer in this capacity and showing large savings. Desires further connection with a limited number of manufacturing power-users, permanent position as advisory engineer with large concern operating a number of plants or commercial proposition with concern manufacturing power plant apparatus.

34 Member, with thorough business training; up-to-date factory manager; good executive and organizer; competent in manufacturing medium and light weight machinery; fully qualified to fill position of responsibility, desires a position.

35 Steam turbine designer with 5 years' experience in charge of experimental work, desires position with firm now building or intending to develop a line of steam turbines.

36 Mechanical engineer, technical graduate, 16 years' practical experience, familiar with hoisting, conveying and general mill machinery, several years experience in charge of work, desires engineering position.

37 Junior Member, graduate engineer, desires a position which will offer a future. Experienced in general manufacturing methods; at present employed as engineer and assistant to general manager of a modern plant embracing power house, pattern department, foundry, carpenter and machine shops. Salary $2000.

38 Junior, 1908, technical graduate, some knowledge of boilers, desires position testing or installing power plant apparatus.

39 Member with 15 years' experience in steam engineering and power plant equipment, drafting-room office and selling, also several years machine design; desires position with consulting engineer or in engineering work with industrial company. Location east of Pittsburg preferred.

40 Young man, ten years shop experience in one of the largest manufacturing and engineering concerns in New York, for the past five years estimating engineer in charge of contract-engineering work; technical graduate; desires position as purchasing engineer or in an engineering construction department. New England or Middle Atlantic States preferred. Can furnish the highest of references.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALGER, Harley C. (Junior, 1908), Mech. Engr., 45 E. 16th St., Chicago Heights, Ill.

BAENDER, Fred. Geo. (Junior, 1909), Mech. Engr., 310 E. 18th Ave., Spokane, Wash.

BEECHER, J. F. (Associate, 1908), Draftsman, Pa. Steel Co., and *for mail*, 523 N. Fourth St., Harrisburg, Pa.

CALEY, Charles J. (1906), Wks. Mgr., Peterboro Lock Mfg. Co., Ltd., and Oriental Hotel, Peterboro, Ont., Canada.

CHAMBERLAIN, George E. (1907), Pres., Lewell Mfg. Co., 1416 Michigan Ave., Chicago, and *for mail*, 102 S. Waiola Ave., La Grange, Ill.

CHESTER, C. P. (Associate, 1908), Cons. Engr., 512 Caples Bldg., El Paso, Texas.

COMSTOCK, Charles Warren (Associate, 1906), Pres., Comstock-Wellman Bronze Co., 6017 Superior Ave., and *for mail*, 8803 Euclid Ave., Cleveland, O.

COOKE, Thomas F. (Junior, 1904), Cons. Engr., Webb & Cooke, 338 Ellicott Sq., and *for mail*, 618 Delaware Ave., Buffalo, N. Y.

FULWEILER, John Edwin (Junior, 1908), United Gas Improvement Co., and *for mail*, 4335 Chestnut St., Philadelphia, Pa.

GUMP, Walter B. (Junior, 1902), Mech. Engr., 2510 Juliet St., Los Angeles, Cal.

INGALLS, Fred. D. B. (1909), Cons. Mech. Engr., Rosenblum Bldg., 106 E. Fayette St., Syracuse, N. Y.

JOHNSON, Paul F. (1905), Johnson Service Co., Milwaukee, Wis.

KEITH, Thomas M. (Junior, 1905), Robins Conveying Belt Co., 30 Church St., New York, N. Y.

LAIDLAW, Walter (1889), Manager, 1905–1908; Intl. Steam Pump Co., 115 Broadway, New York, N. Y.

LEWIS, Wm. Yorath (1902), Engr., 49 Queen Victoria St., London, E. C., England.

MacKENZIE, Donald (Junior, 1902), Swift & Co., Stock Yards Sta., Chicago, Ill.

MORRISON, Clarke J. (1909), 52 E. 19th St., New York, N. Y.

NEILER, Samuel Graham (1907), Cons. Engr. and Pres., Pierce, Richardson & Neiler, 1407–1411 Manhattan Bldg., Chicago, and Oak Park, Ill.

NIBECKER, Karl (Junior, 1908), Mech. Engr., Southwark Fdy. & Mch. Co., Fifth and Washington Ave., Philadelphia, and *for mail*, Glen Mills, Pa.

POTTS, S. Warren (1909), 628 W. 148th St., New York, N. Y.

SCHAKEL, Jacob Daniel (Associate, 1907), Otis Elev. Co., Northland Ave. and Girder St., Buffalo, N. Y.

SCHREUDER, Andrew M. (1898; 1909), Supt., Philadelphia Textile Mchy., Co., Hancock and Somerset Sts., Philadelphia, and *for mail*, 5351 Wayne Ave., Germantown, Philadelphia. Pa.

SCOTT, Walter G. (Junior, 1909), Allis-Chalmers Co., and *for mail*, University Club, West Allis, Wis.

SPENCER, Frank C. (Associate, 1908), Mech. and Constr. Engr., 5258 Indiana St., Chicago, Ill.

STARBUCK, George F. (Junior, 1901), Draftsman, Boston Elev. Ry., Boston, and *for mail*, Waltham, Mass.

SMITH, S. H. (Associate, 1907), Supt., North Melbourne Elec. Tramways & Ltg. Co., Ltd., Mt. Alexander Rd., and Clydehall, Harding and East Sts., Ascot Vale, Melbourne, Australia.

TAYLOR, Cecil Hamelin (Associate, 1908), Ch. Engr., Hudson Motor Car Co., and Pasadena, Detroit, Mich.

TREGELLES, Henry (1888), Bartolome Mitre 544, Buenos Aires, and Hurlingham and Pacifico, Buenos Aires, Argentine Repub., South America.

VON AMMON, Siegfried (1904; 1905), Fontella, Va.

WADDELL, Charles E. (1903; 1907), Cons. Engr., 78 Patton Ave., Asheville, N. C.

WALKER, Gilbert S. (1904), Isthmian Canal Com., Mills Bldg. Annex, Washington, D. C.

WHEELER, Earl (Junior, 1907), Elec. and Mech. Engr., Elec. Speedometer & Dynamometer Mfg. Co., 1317 New York Ave., and *for mail*, The Benedict, 1810 I St., N. W., Washington, D. C.

WHEELER, Wm. Trimble (1905), 286 Greenwich St., and 340 W. 21st. St., New York, N. Y.

NEW MEMBERS

ARBOGAST, Victor R. (1909), Wks. Engr. and Supt., Natl. Radiator Gesellschaft, Schoenebeck Elbe, Germany.

BACON, John Lord (1899; 1909), Engr. and Supt. of Constr., R. P. Shields & Son, 605 Scripps Bldg., and *for mail*, 3576 A St., San Diego, Cal.

BLUM, Arthur N. (1909), Asst. Mgr., Sormovo Engrg. Wks., Nijni Novgorod, Russia.

BORNHOLT, Oscar Charles (1904; 1909), Mech. Engr., Ford Motor Co., Piquette Ave. and Beaubien St., and *for mail*, 50 Philadelphia Ave., Detroit, Mich.

DAY, Leonard A. (1909), First Asst. Mech. Engr., St. Louis Water Dept., and *for mail*, 4015 Greer Ave., St. Louis, Mo.

DIMAN, W. G. (1909), Senior Engr. Officer, U. S. S. Mayflower, Navy Dept., Washington, D. C.

FERRIER, Joseph J. (Junior, 1909), So. Pacific Co., 1110 Flood Bldg., San Francisco, Cal.

FRANK, Edwin (Junior, 1909), Designer, Maffei-Schwartzkopff Wks., G. m. b. H., and *for mail*, Kaiser Wilhelmstr., 10, Zeuthen i M, Germany.

HERRIMAN, Victor D. (Junior, 1909), Engr., Intl. Steam Pump Co., 115 Broadway, New York, and *for mail*, 167 Quincy St., Brooklyn, N. Y.

HORTON, Charles M. (Junior, 1909), Secy., Ford Refrig. Air-Machine Co., and *for mail*, 101 W. 101st St., New York, N. Y.

KNEELAND, Frank H. (Junior, 1909), Mech. Engr., U. S. Coal & Coke Co., Gary, W. Va.

PARSONS, Edmund S. (Junior, 1909), Mech. Engr., Remington Typewriter Wks., and *for mail*, 56 West St., Ilion, N. Y.

POLHEMUS, Louis Edward (Junior, 1909), Asst. M.M., Mexican Light & Power Co., Necaxa (Estado de Puebla), Mexico.

POOLE, Cecil P. (1909), Joint Editor, Power and The Engineer, 505 Pearl St., New York, N. Y., and South Orange, N. J.

RANSOM, T. Wells (1909), Cons. Mech. Engr., Board of Public Wks., San Francisco, Cal.

SOVERHILL, Harvey A. (1909), Supt., Root & Van Dervoort Engrg. Co., East Moline, and 623 23d St., Moline, Ill.

TORRANCE, Chas. Everett (Junior, 1909), Instr., Sibley College, and *for mail*, 638 Stewart Ave., Ithaca, N. Y.

DEATHS

BALDWIN, Stephen W.
BATCHELOR, Charles.
SANGUINETTI, Percy A.

GAS POWER SECTION

CHANGES OF ADDRESS

BAENDER, Fred Geo. (1909), Mem. Am.Soc.M.E.
FISKE, Geo. Wallace (Affiliate, 1909), 610 W. 10th St., Topeka, Kan.
MYERS, Theodore B. (Affiliate, 1909), Woodcliff-on-Hudson, N. J.
PARKER, Lewis C. (Affiliate, 1908), present address unknown.

NEW MEMBERS

COLLINS, Harold W. T. (Affiliate, 1910), Designer, Lodge & Shipley Mch. Tool Co., Cincinnati, and *for mail*, 2242 Cameron Ave., Norwood, O.
CRAIG, James (1910), Mem. Am.Soc.M.E.
DORSEY, Howard Alex. (Affiliate, 1910), Instr. Mech. Engrg., Univ. of Cincinnati, Cincinnati, O.
FERRIER, Joseph J. (1910), Mem. Am.Soc.M.E.
GARDNER, F. M. (Affiliate, 1910), Engr. and Salesman, Fairbanks, Morse & Co., and *for mail*, 137 W. Fourth St., Cincinnati, O.
GRIFFITHS, Leonard L. (1910), Mem. Am.Soc.M.E.
JEWETT, Arthur C. (1910), Mem. Am.Soc.M.E.
MANGELSDORFF, Max F. (Affiliate, 1910), 115 Nassau St., New York, N. Y.
POOLE, Cecil P. (1909), Mem.Am.Soc.M.E.
READ, Carleton A. (1910), Mem. Am.Soc.M.E.
ROE, Joseph W. (1910), Mem. Am.Soc.M.E.
SCHWENKER, Robert Frederick (Affiliate, 1910), Mech. Engr., 3913 Regent Ave., Norwood, O.
TORRANCE, Charles E. (1910), Mem. Am.Soc.M.E.
WHITTLESEY, James Thomas (1910), Mem. Am. Soc. M. E.

STUDENT BRANCHES

CHANGES OF ADDRESS

DUNSHEATH, L. M. (Student, 1909), 105 E. Healey St., Champaign, Ill.
GROSSBERG, Arthur S. (Student, 1909), Mineral Point Zinc Co., Depue, Ill.
HERBERT, E. H. (Student, 1909), Doak Gas Eng. Co., 7–9 First St., San Francisco, Cal.
KOWALEWSKI, A. J. (Student, 1910), 582 Main Bldg., State College, Pa.
MANSFIELD, W. M. (Student, 1909), 2924 Mt. Vernon Ave., Milwaukee, Wis.
ROMIG, F. G. (Student, 1910), 601 S. Wright St., Champaign, Ill.
TIFFT, R. H. (Student, 1909), 65 Park Avenue, New York, N. Y.

NEW MEMBERS

COLUMBIA UNIVERSITY

BAUM, A. L. (Student, 1910), 252 W. 128th St., New York, N. Y.
BLUMENFELD, Ralph (Student, 1910), 508 W. 114th St., New York, N. Y.
BRETTELL, C. (Student, 1910), 29 Meadow Lane, New Rochelle, N. Y.
FRAMBACH, F. S. (Student, 1910), 430 W. 119th St., New York, N. Y.
GATELY, W. A. (Student, 1910), 125 E. 54th St., New York, N. Y.
GUITERAS, J. G. (Student, 1910), 1 Livingston Ave., Yonkers, N. Y.
HAYNES, J. L. (Student, 1910), 3216 Glenwood Rd., Brooklyn, N. Y.
JAROS, A. L. (Student, 1910), 542 W. 112th St., New York, N. Y.
KATZ, E. J. (Student, 1910), 249 E. 68th St., New York, N. Y.
KIRSCHBERG, M. (Student, 1910), 25 W. 123d St., New York, N. Y.
LACY, F. T. (Student, 1910), 411 W. 115th St., New York, N. Y.
LORD, J. W. (Student, 1910), 163 E. 71st St., New York, N. Y.

CORNELL UNIVERSITY

BENBOW, J. R. (Student, 1910), 210 Linden Ave., Ithaca, N. Y.
HAM, C. W. (Student, 1910), 126 E. Seneca St., Ithaca, N. Y.
PIMPER, T. F. (Student, 1910), 427 E. Seneca St., Ithaca, N. Y.
ROBINSON, G. E. (Student, 1910), 208 Williams St., Ithaca, N. Y.
STURGIS, R. F. (Student, 1910), 110 Sage Pl., Ithaca, N. Y.

BROOKLYN POLYTECHNIC INSTITUTE

BARRETT, S. A. K. (Student, 1910), 114 Pierrepont St., Brooklyn, N. Y.
ERICSON, E. O. (Student, 1910), Helmetta, Middlesex Co., N. J.
GRIFFIN, E. F. (Student, 1910), Box 417, Oyster Bay, L. I., N. Y.

PENNSYLVANIA STATE COLLEGE

FORKER, Geo. M. (Student, 1910), 203 McAllister Hall, State College, Pa.
KAIER, John B. (Student, 1910), 283 Lehigh St., Wilkes-Barre, Pa.
MARSH, Karl H. (Student, 1910), The Lincoln, Youngstown, O.
PERHAM, Dean E. (Student, 1910), 512 Main Bldg., State College, Pa.
WESTERMAN, John H. (Student, 1910), Theta Psi House, State College, Pa.

STATE AGRICULTURAL COLLEGE OF OREGON

GRAF, Samuel Herman (Student, 1910), State Agri. College of Oregon, Corvallis, Oregon.
HASKELL, William Dexter (Student, 1910), State Agri. College of Oregon, Corvallis, Oregon.
LINES, J. Donald (Student, 1910), State Agri. College of Oregon, Corvallis, Oregon.

STEVENS INSTITUTE OF TECHNOLOGY

BRUCE, A. C. (Student, 1910), 934 Bloomfield St., Hoboken, N. J.
MONESTEL, Alberto A. (Student, 1910), 518 Hudson St., Hoboken, N. J.
SCHOCH, Floyd W. (Student, 1910), 507 River St., Hoboken, N. J.

UNIVERSITY OF ILLINOIS

BANNISTER, B. (Student, 1910), 412 E. Green St., Champaign, Ill.
HASBERG, Will (Student, 1910), 307 E. Green St., Champaign, Ill.
MURDUCK (Student, 1910), 705 W. Hills St., Champaign, Ill.

UNIVERSITY OF KANSAS

FAIRCHILD, F. P. (Student, 1910), 946 Ohio St., Lawrence, Kan.

COMING MEETINGS

MARCH–APRIL

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN ASSOCIATION OF RAILROAD SUPERINTENDENTS

March 18, Chicago. Secy., O. G. Fetter.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

March 11, with Am. Soc. M. E., 29 W. 39th St., New York. Papers: Electric Mine Hoists with Illgner Motor Generator Set, R. R. Seeber; Comparison of Electric and Compressed Air Drives for Mine Hoists, W. Sykes. March 30-April 1, Selwyn Hotel, Charlotte, N. C. Papers: Economics of Hydroelectric Plants, W. S. Lee, Mem. Am. Soc. M. E., Electric Drive in Textile Mills, A. Milmow; Gas Engines in City Railway and Light Service, E. D. Latta, Jr.; Protecting Insulators from Lightning and Power Arc Effects On Lines of the Niagara and Lockport Power Co., L. C. Nicholson. Secy., R. W. Pope. April 21, San Francisco, Cal. Papers : Economics of a Generator Power System, P. M. Downing; Hydroelectric Developments and Irrigation, J. C. Hays.

AMERICAN INSTITUTE OF MINING ENGINEERS

March 1-5, Spring Meeting, Hotel Schenley, Pittsburg, Pa. Secy., R. W. Raymond, 29 W. 39th St., New York.

AMERICAN MATHEMATICAL SOCIETY

April 30, Columbia University, 150 W. 116th St., New York. Secy., F. N. Cole.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

March 14-17, Chicago. Secy., E. H. Field, Monadnock Bldg.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION

March 15–17, annual convention, Chicago. Secy., E. H. Fritch, 962 Monadnock Blk.

AMERICAN SOCIETY OF CIVIL ENGINEERS

March 2, 1910, 220 W. 57th St., New York. Paper: The Improved Water and Sewage Works of Columbus, O., J. H. Gregory. Secy., C. W. Hunt.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

March 8, 29 W. 39th St., New York. March 11, Auditorium Edison Electric Illuminating Co. of Boston, Boston, Mass. May 31-June 3, Spring Meeting, Atlantic City, N. J. July 26-29, meeting in Birmingham, England. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SUPPLY AND MACHINERY MANUFACTURERS ASSOCIATION

SOUTHERN SUPPLY AND MACHINERY DEALERS ASSOCIATION

April 5–7, Seminole Hotel, Jacksonville, Fla.

AMERICAN WATERWORKS ASSOCIATION

April 26-30, annual convention, New Orleans, La. Secy., J. M. Diven, 14 George St., Charlestown, S. C.

BROOKLYN ENGINEERS CLUB

March 3, monthly meeting, 117 Remsen St. Paper: The Making of a Marble Quarry, by T. B. Hamilton. Secy., Joseph Strachan.

BOSTON SOCIETY OF ARCHITECTS

March 1, regular meeting with reports, Parker House. Secy., E. J. Lewis, Jr.

BOSTON SOCIETY OF CIVIL ENGINEERS

March 2, annual meeting, Boston City Club, 7.30 p.m. Paper: Ventilation of Subways, G. A. Soper.

CANADIAN FORESTRY ASSOCIATION

March 10-11, Fredericton, N. B. Secy., Jas. Lawler, 11 Queen's Park, Toronto, Ont.

CANADIAN FREIGHT ASSOCIATION

April 14, annual meeting, Montreal. Secy., T. Marshall, Toronto, Ont.

CANADIAN MINING INSTITUTE

March 2-4, annual meeting, Toronto, Ont. Secy., H. Mortimer-Lamb, Windsor Hotel, Montreal.

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA

March 1, Fulton Bldg., Pittsburg, 8 p.m. Discussion on Present-Day Needs in Structural Materials. Secy., E. K. Hiles.

FLORIDA ELECRTIC LIGHT AND POWER ASSOCIATION

April 12, annual meeting, Tampa. Secy., G. I. Doig, Gainesville.

IOWA ASSOCIATION CEMENT USERS

March 9-11, Cedar Rapids. Secy., Ira Williams, Ames.

IOWA ELECTRICAL ASSOCIATION

April 20-21, annual convention. Secy., W. N. Keiser, Des Moines.

IOWA STREET AND INTERURBAN RAILWAY ASSOCIATION

April, Sioux City. Secy., L. D. Mathes.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Student Branch, Am. Soc. M. E.

March 8, annual meeting, Boston. Secy., A. P. Truette.

MINNESOTA ELECTRIC ASSOCIATION

March, St. Paul. Secy., B. W. Cowperthwait.

MISSOURI ELECTRIC, GAS, RAILWAY AND WATERWORKS ASSOCIATION.

April 14-16, Jefferson City. Secy., C. L. Clary, Sikeston.

MODERN SCIENCE CLUB

March 29, annual dinner; April 12, annual election, 125 S. Elliott Pl., Brooklyn, N. Y. Secy., J. A. Donnelly.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS

April 27–28, semi-annual meeting. Secy., Dr. C. J. H. Woodbury, Mem. Am. Soc. M. E., Box 3672, Boston.

NATIONAL MACHINE TOOL-BUILDERS ASSOCIATION

May, Spring Convention, Rochester, N. Y. Secy., C. Hildreth, Worcester, Mass.

NEW ENGLAND RAILROAD CLUB

March 8, annual meeting, Copley Square Hotel, Boston. Subject for Discussion: M. C. B. Rules of Interchange. Secy,. G. H. Frazier, 10 Oliver St.

NEW ENGLAND STREET RAILWAY CLUB

March 24, annual meeting, Boston, Mass. Secy., J. J. Lane, 12 Pearl St.

NEW ENGLAND WATERWORKS ASSOCIATION

April 13, special meeting, Hartford, Conn. June, Providence, R. I. September 14-16, annual convention, Rochester, N. Y. Secy., Willard Kent, Narrangansett Pier, R. I.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS

March 22, April 26; West Hall, R. I. School of Design, 8 p. m. Papers: The Fitchburg Plan of Coöperative Industrial Education, W. B. Hunter, M. A. Coolidge; Oxy-Acetylene Welding and Cutting, Henry Cave. Secy., Prof. T. M. Phetteplace, Mem. Am. Soc. M. E., 48 Snow St.

RAILWAY SIGNAL ASSOCIATION

March 14, Chicago. Secy., C. C. Rosenberg, Bethlehem, Pa.

SOCIETY OF CHEMICAL INDUSTRY

April 1, annual meeting, New England section. Secy., Alan Claflin, 88 Broad St., Boston, Mass.

STEVENS ENGINEERING SOCIETY

March 1, 8, 15, 22, 31, Hoboken, N. J. Papers: Automobiles, J. F. O'Rourke, H. F. Cuntz; Arts and Industries of the Orient, W. J. Hammer, C. R. Richards; on the Gyrostat and its Applications, G. V. Wendell. Secy., R. H. Upson.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
March			
2	Wireless Institute	S. L. Williams	7.30
3	Blue Room Engineering Society	W. D. Sprague	8.00
5	Amer. Soc. Hungarian Engineers and Architects	Z. deNémeth	8.30
8	The American Society of Mechanical Engineers	Calvin W. Rice	8.15
10	Illuminating Engineering Society	P. S. Millar	8.00
11	American Institute of Electrical Engineers	R. W. Pope	8.00
15	New York Telephone Society	T. H. Lawrence	8.00
18	New York Railroad Club	H. D. Vought	8.15
23	Municipal Engineers of the City of New York	C. D. Pollock	8.15
April			
2	Amer. Soc. Hungarian Engineers and Architects	Z. deNemet	8.30
6	Wireless Institute	S. L. Williams	7.30
7	Blue Room Engineering Society	W. D. Sprague	8.00
8	American Institute of Electrical Engineers	R. W. Pope	8.00
12	The American Society of Mechanical Engineers	Calvin W. Rice	8.15
14	Illuminating Engineering Society	P. S. Millar	8.00

Date	Society	Secretary	Time
April			
15	New York Railroad Club	H. D. Vought	8.15
19	New York Telephone Society	T. H. Lawrence	8.00
27	Municipal Engineers of the City of New York	C. D. Pollock	8.15

OFFICERS AND COUNCIL

PRESIDENT

George Westinghouse ....Pittsburg, Pa.

VICE-PRESIDENTS

Geo. M. Bond ....Hartford, Conn.
R. C. Carperter ....Ithaca, N. Y.
F. M. Whyte ....New York

Terms expire at Annual Meeting of 1910

Charles Whiting Baker ....New York
W. F. M. Goss ....Urbana, Ill.
E. D. Meier ....New York

Terms expire at Annual Meeting of 1911

PAST PRESIDENTS

Members of the Council for 1910

John R. Freeman ....Providence, R. I.
Frederick W. Taylor ....Philadelphia, Pa.
F. R. Hutton ....New York
M. L. Holman ....St. Louis, Mo.
Jesse M. Smith ....New York

MANAGERS

Wm. L. Abbott ....Chicago, Ill.
Alex. C. Humphreys ....New York
Henry G. Stott ....New York

Terms expire at Annual Meeting of 1910

H. L. Gantt ....Pawtucket, R. I.
I. E. Moultrop ....Boston, Mass.
W. J. Sando ....Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft ....Philadelphia, Pa.
James Hartness ....Springfield, Vt.
H. G. Reist ....Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

William H. Wiley ....New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt ....New York

HONORARY SECRETARY

F. R. Hutton ....New York

SECRETARY

Calvin W. Rice ....29 West 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Alex. C. Humphreys, *Chairman*
Chas. Whiting Baker, *Vice-Chairman*
F. R. Hutton
H. L. Gantt
F. M. Whyte

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	1909			
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Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	R. N. Trane	G. A. Glick
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. E. Dudley	F. T. Kennedy
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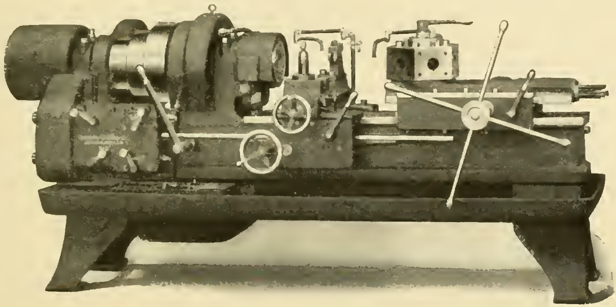

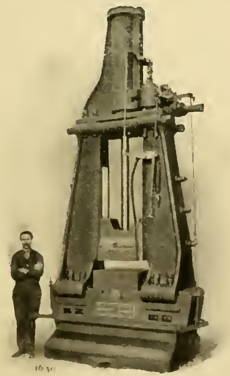

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The inherent weaknesses of the double slide tool support as used in the engine lathe, brass lathe and other machine tools will be fully set forth in the more complete story which follows the catalog section of this book, so that here it is only necessary to say that accurate work is obtained from such machines only at the expense of eternal vigilance of the lathe hand; for such machines are unreliable both in control of the tool in operation and in the return of the tool to its former position for the purpose of doing duplicate work.

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No. 3, 1882	No. 7, 1886	No. 14, 1893, January
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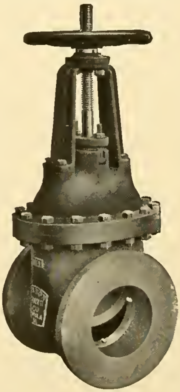

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Mechanical Engineers, N. Y. Vols. 1-4. 1881-1882.
Scientific American. First Series. Vol. 1.
Die Gasmotorentechnick. Vols. 1-5, 6. Nos. 1-9.
Le Génie Civil. Vols. 1-23. 1880-1892.
Glaser's Annalen für Gewerbe u. Bauwesen. Vols. 1-7. 1865-1889.
Verein Deutscher Ingenieure. Vols. 1-7. 1857-63.
Der Schiffbau. Vols. 1-8.

The American Society of Mechanical Engineers

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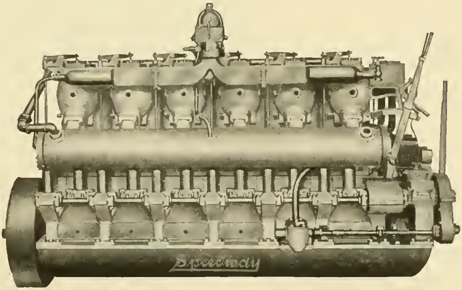

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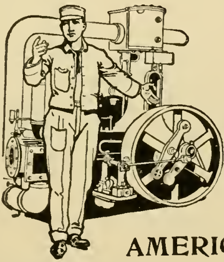

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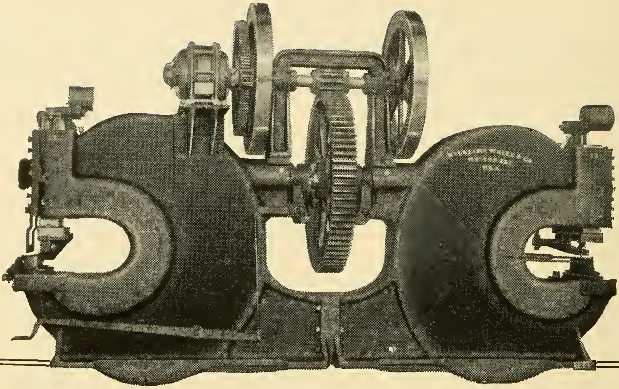

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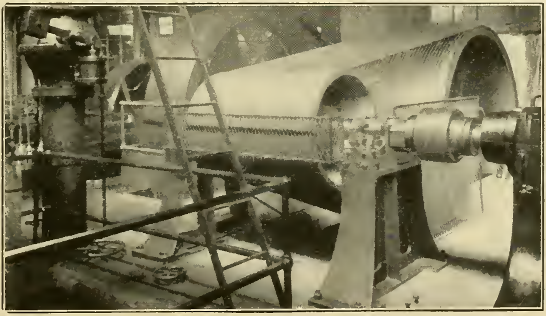

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THE

JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

APRIL 1910

MEETINGS OF THE SOCIETY: ST. LOUIS, APRIL 9; NEW YORK, APRIL 12; BOSTON, APRIL 27; SPRING MEETING, ATLANTIC CITY, MAY 31 TO JUNE 3. MEETING IN ENGLAND, JULY 26 TO 29

APRIL 1910 VOL. 32 No. 4

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The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 APRIL 1910 NUMBER 4

THE St. Louis monthly meeting for April will be held Saturday evening, April 9, with the American Institute of Electrical Engineers and The Engineers' Club of St. Louis coöperating. The subject of the meeting will be The Electric Drive in the Machine Shop, with four papers constituting a comprehensive symposium, both from the standpoint of the mechanical equipment of machine tools and from the economic side of the saving to be effected by the installation of different types of motor drives.

Three of the papers are contributed by The American Society of Mechanical Engineers as follows: The Economy of the Electric Drive, by A. L. DeLeeuw, Mem. Am. Soc. M.E., published in The Journal for November 1909; The Economical Features of Electric Motor Applications by Charles Robbins, Assoc.Mem.A.I.E.E.; Mechanical Features of Electric Driving, by John Riddell, Mem. Am.Soc.M.E. The two latter papers are published in this number of The Journal.

The American Institute of Electrical Engineers have contributed a paper by Charles Fair upon Selection and Methods of Application of Motors and Controllers.

MEETING IN NEW YORK APRIL 12

The New York monthly meeting for April will be held in the Auditorium of the Engineering Societies' Building, Tuesday evening, April 12, the American Institute of Electrical Engineers coöperating. The subject of the The Electric Drive in the Machine Shop will be

discussed and the four papers previously mentioned in the announcement of the April St. Louis meeting will be presented by Messrs. A. L. De Leeuw, Charles Robbins, John Riddell and Charles Fair.

There will be discussions by Messrs. Gano Dunn, Vice-president of the Crocker-Wheeler Company, Ampere, N. J., Clarence L. Collens, President, Reliance Electric and Engineering Company, Cleveland, H. A. Hornor, Electrical Engineer, Philadelphia, Charles Day of Dodge & Day, Philadelphia, Henry Hess of Philadelphia, and other prominent engineers, among them an official representative of the Machine Tool Builders Association, who will report upon the efforts of this Association at standardization of electric motor equipment.

MEETING IN BOSTON APRIL 27

The Boston monthly meeting of the Society, April 27, in which the American Institute of Electrical Engineers, Boston Section, and the Boston Society of Civil Engineers, will coöperate, will be the occasion of the presentation of a paper by Prof. C. M. Allen of Worcester Polytechnic Institute, Mem. Am. Soc. M. E., on The Testing of Water Wheels after Installation, published in this issue of The Journal. The meeting will be held at 8 p.m., in the hall of the Edison Electric Illuminating Company, 39 Boylston St.

Preliminary announcement is also made of the May meeting, to be held May 18, in charge of the Boston Section of the American Institute of Electrical Engineers, with The American Society of Mechanical Engineers and the Boston Society of Civil Engineers coöperating. The gathering will be addressed by Lewis B. Stilwell, President Am. Inst. E. E., on the subject of conservation, especially of water power. The place of meeting will be announced by the American Institute of Electrical Engineers to members of the three societies.

MEETING IN NEW YORK, MARCH 8

The New York monthly meeting for March, in which the American Institute of Electrical Engineers coöperated, was the largest monthly meeting of the Society held during the present season. The paper by H. G. Stott, Mem. Am. Soc. M. E., and J. S. Piggott, on tests on the 15,000-kw. steam-engine-turbine unit located in the 59th Street Station of the Interborough Rapid Transit Company of New York, aroused an unusual amount of interest.

The attendance at the meeting was nearly 700, and the audience remained until a late hour to listen to the comments of those who wished to speak from the floor.

After the presentation by Mr. Stott of the main facts regarding these tests and the installation of the low-pressure turbine on which the tests were made, Mr. Piggott gave an interesting account of the methods used in conducting the tests, illustrating his talk with lantern slides.

A summary of the discussion at this meeting, together with an abstract of that given at the recent Boston meeting which Mr. Stott addressed on the subject of Low-pressure Turbines, and the topical discussion on Steam Turbines given at a meeting of the Society in St. Louis, will be published together in a subsequent issue.

MEETING IN BOSTON, MARCH 11

A meeting of the Society was held in Boston, March 11, in which the Boston Section of the American Institute of Electrical Engineers and the Boston Society of Civil Engineers coöperated. The total attendance was 125. Chairman Hollis said in his introductory remarks that in future all these gatherings would probably be meetings not of one society but of engineers in general, thus inaugurating a new movement among the engineering societies of the country of pretty thorough coöperation. As a result of the meeting on January 21, a committee of fifteen, representative of twelve of the thirty or forty different societies in the vicinity of Boston having especial scientific and engineering interests, had been formed and had under consideration the possibility of erecting an engineering building and perhaps organizing within it a club, as well as providing rooms for the various societies and a meeting place for such gatherings as this. This movement, he thought, would not only bring together the various societies but should serve to relate the engineering profession more closely to civic questions in Boston.

Magnus W. Alexander of Lynn, Mass., Mem.Am.Soc.M.E., presented his paper on The Training of Men, a Necessary Part of a Modern Factory System, published in The Journal for January. This was discussed by Henry E. Rhoades, Past Assistant Engineer, U. S. N., Retired, Prof. Chas. F. Park and R. H. Smith of the Massachusetts Institute of Technology, Prof. Ira N. Hollis, Mem. Am.Soc.M.E., Prof. Gardner C. Anthony, Mem.Am.Soc.M.E., Prof. Peter Schwamb, Mem.Am.Soc.M.E., Luther D. Burlingame, Mem.Am.Soc.M.E., G.

C. Ewing, Assoc.Am.Inst.E.E., S. Fred Smith, President, New England Section of the National Electric Light Association, H. S. Knowlton, Prof. Edward F. Miller, of the Massachusetts Institute of Technology, Mem.Am.Soc.M.E., and Dickerson G. Baker, Mem.Am.Soc.M.E.

MEETING IN ST. LOUIS, MARCH 12

A topical discussion was held by the Society and the Engineers' Club of St. Louis, in the club rooms on Olive Street, Saturday evening, March 12, on the subject of Flywheels. The discussion was opened by Dr. C. H. Benjamin, Mem.Am.Soc.M.E., Dean of the Schools of Engineering of Purdue University, who reviewed the recent developments in testing flywheels and gave an account of the latest apparatus and testing pit for this purpose at Purdue University. There were present at the meeting, Jesse M. Smith, Past-President, Col. E. D. Meier, Vice-President, and Calvin W. Rice, Secretary of this Society. An informal dinner was held before the meeting at the Mercantile Club, attended by the guests and local members.

As is customary when it is impossible for the president to be present, a vice-president is invited to preside, and Col. E. D. Meier, Vice-President, acted as chairman. The presiding officer and William H. Bryan, Chairman of the Local Committee, took the opportunity, previous to the topical discussion, to give the greetings of the Council to the members, and to explain the interest on the part of the Council in the meetings of the Society in the several cities and the appreciation by the Local Committee of their efforts. It was explained that all meetings of the Society are conducted under the same rules, wherever held, the national character of the Society being in this way developed; and at the same time the members are enabled to get the greatest benefits from their association.

Professor Benjamin, who has for many years conducted experiments on flywheels with a view to determining the bursting strength of different types of wheels, followed with his remarks on the subject, after which there was a general discussion.

SPRING MEETING ATLANTIC CITY

RAILROAD TRANSPORTATION NOTICE

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

Special concessions have been secured for members and guests attending the Spring Meeting in Atlantic City, May 31 to June 3, 1910.

The special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below. Read item *g*.

a Buy your ticket at full fare for the going journey, between May 27 and June 2 inclusive. At the same time request a certificate, *not a receipt*. This ticket and certificate should be secured at least half an hour before the departure of the train.

b Certificates are not kept at all stations. Ask your station agent whether he has certificates and through tickets. If not, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point, and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to S. Edgar Whitaker, office manager at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after June 3.

d An agent of the Trunk Line Association will validate certificates, June 1, 2, 3. No refund of fare will be made on account of failure to have certificate validated.

e One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

f If certificate is validated, a return ticket to destination can be purchased, up to June 8, on the same route over which the purchaser came, at three-fifths the rate.

g Members and guests from New York City should buy the regular round trip tickets at $5 and show the return portion to Mr. Whitaker or the validating agent.

The special rate is granted only for the following:

The Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

The Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

The New England Passenger Association except via N. Y. O. & W. R. R. and Eastern Steamship Co. The Rutland R. R. participates in fares reading via its road:

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

The Western Passenger Association offers revised one-way fares, on the basis of two cents per mile, to Chicago, Peoria and St. Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs:

North Dakota, South Dakota, Nebraska, Kansas, Colorado, east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri, north of a line through Kansas, Jefferson City and St. Louis; Illinois, north of a line from Chicago through Peoria to Keokuk.

The Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur; Sault Ste. Marie, Sarnia and Windsor, Ont.

MEETING IN GREAT BRITAIN

Invitations have been received through the Verein Deutscher Ingenieure, to the Königliche Technische Hochschule of Berlin and of Danzig-Langfuhr, as well as the following industrial works:

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Van der Zypen & Charlier, G.m.b.H., Cöln-Deutz
J. Goossens, Aachen (Eschweiler-Aue)
Eschweiler Bergwerksverein, Eschweiler
Gebr. Stumm, G.m.b.H., Neunkirchen (Bez. Trier)
Rheinisch-Nassauische Bergwerks- & Hütten Akt. Ges., Stolberg i/Rhld.
Ehrhardt & Sehmer, G.m.b.H., Schleifmühle, Post Saarbrücken
Dingler'sche Maschinenfabrik A. G., Zweibrücken (Pfalz)
Röchling'sche Eisen- und Stahlwerke, G.m.b.H., Völklingen (Saar)
Maschinen- und Armaturenfabrik vorm. Klein, Schanzlin & Becker, Frankenthal
Stahlwerke Mannheim, Rheinau bei Mannheim
Badische Aktiengesellschaft für Rheinschiffahrt und Seetransport, Mannheim
Heinrich Lanz, Lokomobilen und landwirtschaftliche Maschinen Mannheim (Firma bittet um namentliches Verzeichnis der Teilnehmer nebstAngabe der Firma und deren Branche. Ingenieure solcher Fabriken, die sich mit dem Bau von Lokomobilen und landwirtchaftlichen Maschinen beschäftigen, können an der Beschtigung nicht teilnehmen.)
Aktiengesellschaft vorm. Burgeff & Co., Schaumweinfabrik, Hochheim a/M.
L. Schuler, Werkzeugmaschinenfabrik, Göppingen
Aktiengesellschaft L. A. Riedinger, Maschinen-& Broncewarenfabrik, Augsburg
Maschinenfabrik Augsburg-Nürnberg, Akt:engesellschaft, Nürnberg
Siemens-Schuckertwerke, Nürnberg
Werkzeugmaschinenfabrik Union, vorm. Diehl, Chemnitz
J. E. Reinecker, Werkzeugmaschinenfabrik, Chemnitz-Gablenz
Dresdner Bohrmaschinenfabrik A. G. vorm. Bernhard Fischer & Winsch Dresden-A., Zwickauerstrasse 41–45
Aktiengesellschaft vorm. Gebr. Seck. Mühlenbauanstalt, Dresden–A.
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Beuchelt & Co., Grünberg i/Schles.
A. Borsig, Tegel-Berlin
Siemens-Schuckertwerke, Berlin

Siemens & Halske, Aktiengesellschaft, Berlin
H. Aron, Elektrizitätszahlerfabrik, G.m.b.H., Berlin-Charlottenburg
Allgemeine Elektrizitätsgesellschaft, Berlin
Ludwig Loewe & Co., Aktiengesellschaft Berlin, NW Huttenstr. 17–20
R. Wolf, Lokomobilen, Magdeburg-Buckau
Deutsche Wagenbau-und Leihgesellschaft m.b.H., Danzig
Aktiengesellschaft Amme, Giesecke & Konegen, Mühlenbaustalt Braunschweig
Breslauer Aktiengesellschaft für Eisenbahn-Wagenbau, Breslau

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Material prufüngsanstalt, Laboratorium und Institut der Grossherz. Techn. Hochschule Darmstadt
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Grossherz. Badische chemisch-technische Prüfungs-und Versuchsanstalt, Lehr- und Versuchs-Gasanstalt und andere Institute an der Technischen Hochschule Karlsruhe
Königliches Material prüfungsamt Gross-Lichterfelde West. (Berlin)
Maschinenlaboratorium und elektrotechnisches Laboratorium der Kgl. Technischen Hochschule Breslau. (z. Zt. noch im Ausbau; da die Laboratorien im Juli ds. Jrs. vielleicht betriebsfähig sein können, empfiehlt sich eine vorherige Anfrage beim Rektorat der Hochschule.)

Translations of the invitations from the Königliche Technische Hochschule of Berlin and of Danzig-Langfuhr, with the accompanying letter from the Verein deutscher Ingenieure, follow.

Members of the Society desiring to avail themselves of these courteous invitations will correspond with the Secretary that he may secure them letters of introduction.

VEREIN DEUTSCHER INGENIEURE
Berlin, N. W., Charlottenstrasse, 43

Col. E. D. Meier *Berlin, January 31, 1910*
Care of Heine Safety Boiler Co.,
11 Broadway, New York.

Referring to your correspondence with Dr. Ing. Diesel of Munich, concerning the inspection of German industrial works and scientific institutions by members of The American Society of Mechanical Engineers, we have the honor to send you a list of firms and institutions which have declared themselves ready to receive these gentlemen, and enclose also several letters.

As we are not informed of the traveling route of the members of your highly appreciated Society, and do not know their wishes or preferences, we consider

it advisable that The American Society of Mechanical Engineers should correspond directly with such works and institutions as they would like to visit and arrange the necessary details.

With highest regards,

Business office of the
VEREIN DEUTSCHER INGENIEURE
Linde

MASCHIHENBAULABORATORIUM DER KONIGL, TECHNISCHEN HOCHSCHULE ZU BERLIN

Vorsteher: Prof. E. Josse

Charlottenburg, November, 15, 1909.

Highly honored gentlemen:

I have been informed that on the occasion of your visit to England and the British Institution of Mechanical Engineers, you also think of visiting Germany in order to examine industrial works, scientific institutions, etc.

We would greet with pleasure your visit to the Königliche Technische Hochschule of Charlottenburg, and we would then gladly take the opportunity to show you the various laboratories of the Hochschule, especially the Mechanical Laboratory in all its details.

I beg you therefore to embody in your programme a visit to the above named institution and sign, with especial regards

Cordially,
JOSSE
Professor.

To The American Society of Mechanical Engineers.

MACHINENTECHNISCHES LABORATORIUM DER KGL. TECHNISCHE HOCHSCHULE
Prof. A. Wagener

Danzig-Langfuhr, November, 15, 1909.

To the American Society of Mechanical Engineers:

Having learned through the Verein deutscher Ingenieure that at the conclusion of the Annual Meeting of The American Society of Mechanical Engineers which is to take place about the end of July, 1910, in London, a visit to German industrial works and scientific institutions, is planned, I have the honor to extend a cordial invitation to The American Society of Mechanical Engineers to visit the mechanical laboratory of the Königliche Technische Hochschule at Danzig.

With highest regards

Respectfully
A. WAGENER.

SOCIETY AFFAIRS

MEETING OF THE COUNCIL

A regular meeting of the Council was held March 8, 1910, with E. D. Meier, Vice-President, presiding. There were present Charles Whiting Baker, George M. Bond, John R. Freeman, H. L. Gantt, James Hartness, Alex. C. Humphreys, F. R. Hutton, E. D. Meier, I. E. Moultrop, H G. Reist, Jesse M. Smith, Arthur M. Waitt, and the Secretary. Regrets were received from President Westinghouse and W. F. M. Goss, Vice-President.

The minutes of the meeting of February 8 were read and approved, after being amended to read,

Voted: That the proposed amendments with the report of the Finance Committee, be referred to the Committee on Constitution and By-Laws jointly with the Finance Committee for report back to the Council.

The Secretary announced the deaths of A. M. Goodale and Percy A. Sanguinetti.

The resignations of A. E. Holcomb and H. J. Scales were accepted with regret. The membership of W. W. Bigelow was declared to have lapsed.

The Secretary read the invitation of President Aspinwall of the Institution of Mechanical Engineers, to members of the Council and Past Presidents of this Society, to a dinner on the evening of Monday, July 25. A total of 208 are planning to attend the Joint Meeting in England in July, of whom 135 have arranged to sail on the Celtic.

Letters were read from the Königliche Technische Hochschule of Berlin and of Danzig-Langfuhr, and the Verein deutscher Ingenieure extending invitations to the visiting members of the Society.

Voted: To appoint the following Committee on Land and Building Fund: H. F. Holloway, I. E. Moultrop, F. H. Stillman, Morris L. Cooke, George A. Orrok.

The Secretary stated that the memorial window to Sir Benjamin Baker, Hon. Mem.Am.Soc.M.E., deceased, was presented by the Earl of Cromer in behalf of the subscribers and accepted by the Dean of Westminster Abbey in December 1909, and that report including

a colored illustration of the window was in preparation by the Institution of Civil Engineers.

Resolutions were read from the members of the Society resident in St. Louis, together with the action of the Executive Committee, as follows:

Voted: That a committee to consist of Jesse M. Smith, Past-President, E. D. Meier, Vice-President, I. E. Moultrop, Manager, Willis E. Hall, Chairman of Meetings Committee, and Calvin W. Rice, Secretary, be appointed to represent the Council at the meeting of the Society in St. Louis, March 12.

The committee is instructed to present the greetings of the Council to the St. Louis members, to gather information regarding the meetings of the Society in St. Louis, and to report its findings to the Council together with its recommendations, as soon as practicable.

The communication of February 15 signed by Mr. Wm. H. Bryan, from the members of the Society in St. Louis, together with the communication of February 25 with respect to same from the Meetings Committee, was read; after consideration the Chairman of the Meetings Committee and the Secretary were requested to draft a letter for submission to the Executive Committee and the Council, which shall represent the views of the latter body.

The communication of February 23 from Mr. Wm. H. Bryan, representing the members of the Society in St. Louis, requesting permission to hold a meeting of the Society on March 12, referred by the Meetings Committee to the Executive Committee, was referred back to the Meetings Committee with power, with the suggestion that authorization be given for a topical discussion, namely, The Recent Developments in the Bursting of Flywheels and Pulleys, by Prof. C. H. Benjamin of Purdue University, the authorization to be given under By-Law 23.

Notice was given of the purpose of the Committee on Constitution and By-Laws to amend By-Laws 11, 16, 17, 18, as follows:

FEES AND DUES

B 16 The initiation fee and the annual dues for the first year shall be due and payable on the first day of the month following the date of the election of a Member, Associate or Junior. The annual dues for each ensuing year shall be due and payable in advance on the corresponding day in each year thereafter. Upon the payment of the initiation fee and the annual dues for the first year, the person elected shall be entitled to the rights and privileges of membership in the grade to which he was elected. The date of payment of a member's annual dues may be changed to the first day of any other month, and a *pro-rata* adjustment of the dues made, by application to the secretary.

B 17 A Member, Associate or Junior in arrears for dues for one year, on the first day of October previous to the Annual Meeting, shall not be entitled to

vote, or to receive the Transactions or the publications issued by the Society thereafter until such dues have been paid. Should the arrears for dues or otherwise be for more than two years, the name of such person shall be presented to the Council for such action as it deems advisable under C 24. Should the right to vote, or to receive the publications of the Society be questioned, the books of the Society shall be conclusive evidence.

B 18 The Council may, in its discretion, restore to membership any person dropped from the rolls for non-payment of dues, or otherwise, upon such terms and conditions as it may at the time deem best for the interests of the Society.

ELECTION OF MEMBERS

B 11 Each person elected to membership, except an Honorary Member must subscribe to the Constitution, By-Laws, and Rules of the Society, and pay the initiation fee before he can receive a certificate of membership in the Society. Resignations from membership shall be presented to the Council for action.

It was also voted to approve the adoption of B 22 and B 24, as published in another part of this issue of The Journal.

Voted: To amend Rule 24 to read as follows:

R 24 Engineers and others not members of the American Society, but desiring to participate in the meeting of the Section, may enroll themselves as affiliates as heretofore provided with the approval of the Executive of the section. Such affiliates shall have the privilege of presenting papers and taking part in the discussions. They shall pay $5 per annum which shall be due and payable in advance, on October 1 of each year of their enrollment, and shall thereby be entitled to receive the regular issues of The Journal for a period covered by their dues.

Voted: To amend Rule 29 to read:

R 29 The American Society of Mechanical Engineers will furnish monthly issues of The Journal to all members of affiliated organizations who are not members of The American Society of Mechanical Engineers upon the payment by each of two dollars per year, such payment being due January 1 of each year. The American Society of Mechanical Engineers will furnish gratis to each affiliated body, extra copies of advance papers for use at its meetings, the number furnished to be agreed upon at the discretion of the Secretary.

Voted: To approve the report of the Committee on International Standard for Pipe Threads.

Voted: To refer the communication of John Riddell, suggesting the preservation of models of epoch-making inventions that would be of interest in showing the development of engineering, to a committee of five, consisting of Charles Wallace Hunt, Col. E. A. Stevens, John Riddell, F. R. Hutton, Edward Van Winkle, to report what action if any, should in their judgment be taken. The letter is appended to this report.

Voted: To approve the recommendation of the Executive Committee, with regard to Col. R. S. Crompton's communication respecting the desirability of an international standard for machine screws; that the Secretary be directed to reply that inasmuch as the Society is to meet in England this summer the Institution would possibly be pleased to invite the Society to a conference on this subject; if so, our Society would be pleased to respond by appointing a committee to confer with a committee of the Institution. It was also advised that a suggestion be included regarding the coöperation of the Automobile Engineers of America.

A communication was read from the Verein Deutscher Ingenieure, inviting the coöperation of the Society in securing biographies and reminiscences of our engineers, and it was voted to refer this to the Committee on Society History.

A letter was read from L. B. Stillwell, President of the American Institute of Electrical Engineers, expressing cordial coöperation in the meeting of the Society on April 12.

The meeting adjourned to April 12.

Amendments to B 22 and B 24 Approved by Council

The Council voted to approve under the provision of C 59 the adoption of B 22 and B 24. The Amendment is to take effect immediately, as provided.

FINANCE COMMITTEE

B 22 The Finance Committee shall consist of five Members or Associates. The term of office of one Member of the Committee shall expire at the end of each Annual Meeting. This Committee shall under the direction of the Council, have a supervision of the financial affairs of the society, including the books of account. The Committee may cause the accounts of the Society to be audited and approved annually by a chartered or other competent accountant. The Committee shall hold monthly meetings for the audit of bills and such other business as shall come before it and shall deliver to the Secretary for representation to the Council at the end of each fiscal year, a report of the financial condition of the Society for the past year, and also shall present therewith a detailed estimate of the probable income and expenditure of the Society for the following twelve months. It shall make recommendations to the Council as to investments, and when called upon by the Council, advise upon financial questions. It shall have charge of the making of all contracts and other obligations to pay money in the Society's work and the ordering of all expenditures thereunder.

PUBLICATION COMMITTEE

B 24 The Publication Committee shall consist of five Members or Associates. The term of office of one Member shall expire at the end of each Annual Meeting. The Committee shall review all papers and discussions which have been presented at the meetings, and shall decide what papers and discussions, or parts of the same, shall be printed in the Transactions of the Society. The Committes shall have the supervision of the monthly publication of the Society known ae "The Journal." The Committee will be expected to publish all such data as will be of assistance to engineers or investigators in their work. At the end of each fiscal year the Committee shall deliver to the Secretary for presentation to the Council a detailed report of its work.

Proposed Museum of Mechanic Arts

The communication previously referred to, by John Riddell, proposing a museum of Mechanic Arts, is as follows:

February 26, 1910

To the President and Council
The American Society of Mechanical Engineers,
29 West 39th Street, New York City.

Gentlemen:

The rapid advancement in Mechanic Arts in this country causes machinery and mechanical devices to be quickly superseded by newer developments. Such superseded devices are often most interesting, in studying the development of engineering, but unfortunately such devices disappear, leaving no record of what has been done. Think for a moment how interesting it would be to have the original and a few intervening forms of such American devices as the cotton gin, and a few of the numerous machines which we have made for harvesting cotton, the sewing machine, telephone, phonograph, linotype, telegraph, aeroplane, and other machines, while not of American origin, but to which we have greatly contributed in their development:—as the steam engine, plow, machine tools, general automatic machinery, bicycle, automobile, steam turbine, electric dynamo, and steel mill machinery.

In the South Kensington Museum the epoch-making inventions of Watt and Stephenson are carefully preserved, and visited by thousands of people from all civilized countries.

American Engineers have contributed so much to this work that it is appropriate that a record of the most important developments should be kept. I have thought for some time that a movement should be put on foot to establish a museum of mechanic arts, and that it is most appropriate that this should be done by The American Society of Mechanical Engineers.

It is important if anything is to be done in this line that action should not be delayed, since it will be readily understood that much material is available for such a museum now that could not be had ten years hence.

I am prompted to make this suggestion in view of the forthcoming trip abroad by many of your members and I might also suggest that some investigations ad report be made on the feasibility of such a scheme.

Yours truly

(*Signed*) JOHN RIDDELL.

Members who think a museum of such a character would be desirable are urged to make suggestions in regard to its scope as well as of articles that should be so preserved, or to manifest their interest by assisting to endow the museum or in any other manner.

STUDENT BRANCHES

BROOKLYN POLYTECHNIC INSTITUTE

William Kent, editor of Industrial Engineering and member of the Society, will give an address on Engineering and Common Sense, at the regular meeting of the Brooklyn Polytechnic Student Section, on Saturday evening, April 9, 1910, in the institute chapel, 85 Livingston St., Brooklyn.

PURDUE UNIVERSITY

On March 3, 1910, the Purdue Student Section was addressed by G. A. Weschler (1910), on The Manufacture of Cartridge Cases for the United States Navy. Mr. Weschler's eight years' experience in the Washington navy yard, two years of which were spent in the cartridge case shop, has made him familiar with a manufacturing process not generally known. The various steps in the manufacture were taken up in detail, the talk being illustrated by lantern slides.

STEVENS INSTITUTE OF TECHNOLOGY

The following lectures, of the schedule for 1909-1910, will be delivered before the Stevens Engineering Society: April 5, The Theory of Gyrostatic Motion, by Lewis A. Martin; April 12, Methods and System in Relation to Handling Concrete Work, by Frank B. Gilbreth, Mem.Am.Soc.M.E.; April 19, Notable Examples in Modern Construction, by John C. Ostrup; April 26, Development of the NewNavy, by David Watson Taylor; May 10, The Contribution of Photography to our Knowledge of the Stellar Universe, John A. Brashear, Hon. Mem. Am. Soc.M. E.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The speakers at the annual meeting and banquet of the Mechanical Engineering Society of the Massachusetts Institute of Technology, were Prof. Gaetano Lanza, Mem.Am.Soc.M.E., Honorary Chairman of the organization, Colonel Locke, and C. C. Pierce. The following officers were elected for the ensuing year: Morril MacKenzie, Chairman; H. C. Brown, Vice-Chairman; Foster Russell, Secretary; H. S. Lord, Treasurer; D. P. Allen, H. S. Smith and A. F. Kenrick, Governing Committee.

NECROLOGY

JAMES HENRY BLESSING

James Henry Blessing was born in the village of French's Mills in Albany County, New York, September 14, 1837. At his father's death in 1849 he left school and in 1853 was apprenticed to the machinist trade for four years, with the firm of F. & T. Townsend. He remained with this firm until 1861, when he entered the U. S. Navy as acting assistant engineer. After the war he became engineer in charge of steam machinery of the Brooklyn Horse R. R. Co., returning to Albany in 1868 to act as superintendent of the foundry and machine works of Townsend & Jackson, successors to F. & T. Townsend.

In 1870 Mr. Blessing invented the return steam trap, the best known of his one hundred and twenty inventions. In July 1872 he left the employ of Townsend & Jackson to engage with Genl. Frederick Townsend in the manufacture and sale of these and other steam specialties, under the firm name of Townsend & Blessing. In June 1873 this firm sold their interest to the Albany Steam Trap Company and Mr. Blessing became secretary and treasurer and general superintendent of the company, and afterwards president.

Mr. Blessing was elected mayor of Albany in 1899. He was a member of the Society of Engineers of Eastern New York and of the Albany Historical and Art Society, and entered this Society in 1891. He died in Albany, February 21, 1910.

ALFRED MONTGOMERY GOODALE

Alfred Montgomery Goodale, Manager of the Society, 1898–1901, and a life member, died in Waltham, Mass., December 17, 1909.

He was born in Saco, Me., December 20, 1855, and educated in the public schools of that State, receiving from the Maine State College the degree of B.S. in 1875. He served for five years in the works of the Saco Water Power Machine Shop, Biddeford, Me., and the Bates Mills, Lewiston, Me., building, setting up and running cotton machinery; and in 1880 became superintendent of the Newton Mills, at New-

ton Upper Falls, Mass., afterwards acting as agent, from 1881 to 1883, and from 1884 to 1894, for the Hamilton Woolen Company of Amesbury, Mass., and the Boston Mfg. Co., of Waltham, Mass. Since 1894 he had been treasurer and a director of the Boston Mfg. Co. With each of these companies, Mr. Goodale had charge of the erection of new machinery, engines and boilers, and of the reorganization and improvements of the existing plants. In 1901 he started the firm of A. M. Goodale & Co., of Boston, brokers in cloths and yarns.

Mr. Goodale served on various city commissions and was a trustee of the Waltham hospital. He was a director of the New England and Northwestern Investment Company and of the Westfield Creel Company. Besides his club and Masonic connections he was president of the New England Cotton Manufacturers Association, and a member of this Society since 1886.

J. HENRY SIRICH, JR.

J. Henry Sirich, Jr., associate member of the Society, died January 22, 1910, at Bethlehem, Pa. He was born at Baltimore, Md., April 9, 1881, and received his technical education at the Baltimore Polytechnic Institute, from which he was graduated in the class of 1898. He served his apprenticeship at and afterwards entered the drafting room of the engineering works of Robert Poole & Son Company, now the Poole Engineering & Machine Company of Baltimore.

In April 1903 Mr. Sirich became an assistant engineer on the steamships of the Atlantic Transport Company, remaining with them a year, during which he secured a United States license as second assistant engineer of ocean condensing steamers of 10,000 gross tons. From 1904 to 1908 he was connected with the American Bridge Company at Ambridge, Pa., and the Westinghouse Machine Company, East Pittsburg, Pa. In the latter company he entered first the turbine-testing department, of which he became foreman in September 1905, and later was transferred to the turbine-erecting department of the New York district, as trouble foreman.

In July 1908 he became connected with the power department of the Bethlehem Steel Company and held the position of chief draftsman at the time of his death. Mr. Sirich was accidentally drowned in the Lehigh River at Bethlehem, Pa.

THE TESTING OF WATER WHEELS AFTER INSTALLATION

By Prof. C. M. Allen, Worcester, Mass.

Member of the Society

In the last few years there has been a growing demand for brake tests of water wheels after installation, the object being to determine the horsepower and in many cases the efficiency of the wheels, under actual running conditions, as well as to ascertain whether the wheels are up to their guaranteed rating.

2 The Holyoke testing flume is the only place in the United States where commercial tests of water wheels are made. For purposes of comparison under similar conditions, these tests serve their purpose well and their influence has been great in the development of the modern efficient turbine; but however well a wheel may show up under test made as just described, it may or may not give equally good results after installation. That depends entirely upon the kind of wheel, conditions of setting, and requirements of performance.

3 If the wheel is given a good setting and is allowed to run at the proper speed under a head suited to the design, then it will perform its rated work, which can be accurately computed from the original tests made at Holyoke, provided the wheel is not too large for the testing flume. This flume was not designed to test the largest of our modern turbines, nor is it suitable for testing high-head turbines. If the wheel is not given a fair setting and is required to run at too high a speed (which seems to be almost universal practice), it will fall down on both power and efficiency, the drop in each depending upon the departure from the normal conditions.

4 The efficiency of water wheels under actual working conditions has a very direct bearing upon the conservation of natural resources, and every inducement should be offered to keep that efficiency high. The water wheel as it is leads all other prime movers in efficiency.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

Under ideal working conditions of the steam engine, gas engine and steam turbine, the water wheel has at least three times as good an efficiency as the best of these. If, therefore, by increasing the efficiency of the water wheel, even by a small percentage, we are able to get just so much more power from the same amount of water used, this clearly has a direct bearing on the question of conservation.

5 There is one difference between coal and water, considered as sources of power, which is of more importance than is usually given it, namely: that if water is not used for power, and used efficiently, then that power is lost forever. It is a case of use or lose. The coal not mined or used still remains for the years to come, but the water power not used at all, or not used efficiently, is gone. "The mill will never grind again with the water that is past." As a matter of fact, there are many plants today operated by water turbines that are from 10 to 15 per cent lower in efficiency than they might have been, had the proper kind of installation and setting been definitely known and used. It is, therefore, the desirability of determining the proper setting of the turbine, and the best speed of operation under actual running conditions, that has created, in a large measure, the demand for brake testing after installation.

6 The importance of having a water power developed and operated with maximum efficiency needs no argument; yet of the several reasons that may be mentioned, one of the most important, though apparently not always considered, is purely financial. In the case of several typical hydro-electric installations, for instance, the cost of power house, dam, reservoirs generators, transmission lines, etc., is over 90 per cent of the total, leaving less than 10 per cent for the wheels; but upon the performance of the wheels, depends to a large extent the income from the entire installation. Any increase in the efficiency of these wheels means a direct gain in the power output, and this means, or should mean, not only bigger dividends but also a probable saving of coal somewhere.

7 Wheels have been tested in the last few years in several plants where the difference between the guaranteed efficiency which should have been obtained, and the actual efficiency due to poor settings, was enough to make the difference between a good paying investment and one that did not pay at all.

8 When wheels are installed in hydro-electric stations, and apparently do not show the power and efficiency guaranteed, the question naturally arises, why should a brake test be thought necessary? This may be answered in several ways. In the author's opinion, an

electrical test properly conducted should be sufficiently accurate and reliable in determining the output of the wheels. The reason for making a good many brake tests in the past has been to settle disputes between the hydraulic power and the electrical interests, relative to the guaranteed operation of the plant. The majority of water wheel builders in this country are not willing to abide by the results of an electrical test unless the wheels show up to the guaranteed power by such tests. The generator manufacturers are also unwilling to assume that the generators are low in efficiency, or that their testing apparatus is unreliable. The use of the brake for actually determin-

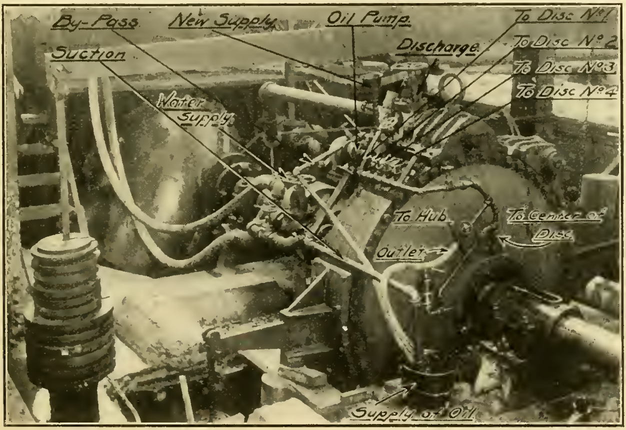

FIG. 1 60-IN. FOUR-DISC DYNAMOMETER; CAPACITY 3000 H.P. AT 200 R.P.M.

ing the horse-power-output of the wheels at the generator coupling is satisfactory to all parties concerned, for the simple reason that the apparatus is very much less complicated and more easily understood. Moreover, the accuracy of the brake can be determined on the ground while under test, as the calibration of the machine can be made at that time, and there is no possible chance for a serious error. In other words, the brake test is the simplest, most accurate, and most direct method of measuring power, and is universally recognized as the standard.

9 In making electrical tests there are many more chances for errors to creep in than in making the brake tests. Ordinarily

several electrical instruments are needed, which should be carefully calibrated before and after tests. These are liable to become changed in transit to the station. Many times they are used under different conditions of temperature, of magnetism, of connection, etc., than when calibrated, and the total results are liable to error on account of the number of instruments to be read, thus bringing in errors which may be more or less cumulative.

10 There is another reason for making brake tests rather than electrical tests at the present time, which is purely a human one. It is that no one but an electrical engineer, or some one with consider-

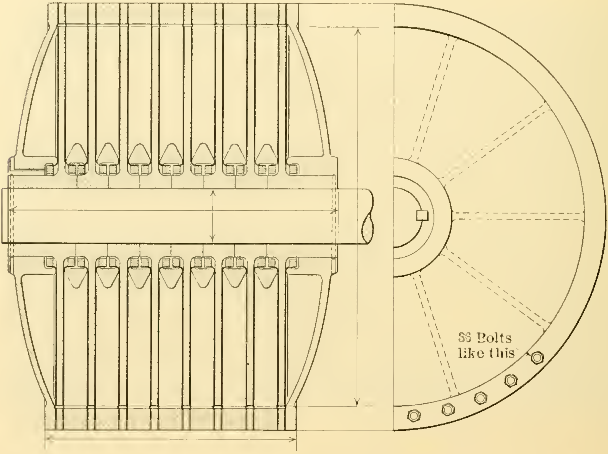

Fig. 2 Assembly Drawing of 28-in. Alden Absorption Dynamometer; Capacity 2000 h.p., 1800 r.p.m.; Eight Discs

able electrical engineering training, can understand the method used on a complete electrical test, while everyone interested in the plant can understand the method of the mechanical brake test. All parties interested can have their representatives on the ground, to check up all the measurements on the brake and calibrate the dynamometer exactly as it is used under running conditions, and so get with certainty the output of the wheels which is to be delivered to the generator. Furthermore, in order to determine the complete characteristics of the wheels under varying gate openings, and with any considerable variation in speed, it is not always practical to use an electrical generator to furnish the load.

11 It was with the idea of meeting this demand that the Alden absorption dynamometer has been developed and built in large sizes. The principle of the dynamometer is so familiar that only a brief description will be given. It is a form of Prony brake, and usually consists of several smooth circular revolvable cast-iron discs (See Fig. 2), keyed to the shaft which transmits the power; a non-revolvable housing having its bearings upon the hubs of the revolving discs; and a pair of thin copper plates in contact with each cast-iron disc, the plates being integral with the housing. Through a system of piping, water under pressure is circulated through chambers between the units, each consisting of a disc and its copper plates, and between

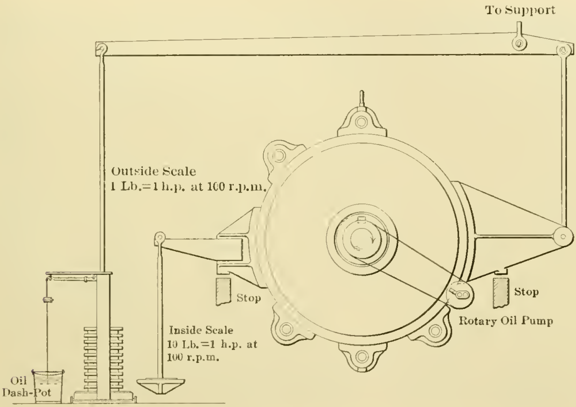

FIG. 3 SKETCH OF DYNAMOMETER SHOWING WORKING PRINCIPLES

the outer plate at either end and the wall of the housing. The water pressure is regulated by hand or by an automatic valve. Another system of piping circulates oil for lubricating the surface of the copper plates next to the revolving discs. In the large-sized machines, oil is impelled by a belt-driven pump mounted on the housing, enters the chambers at the circumference and is forced along the radial grooves of the discs to the hub, and completes its circuit through hose connections to the pump.

12 The power required to drive the pump is measured with, and included in, the power of the dynamometer, for the pump is bolted to the housing, and the driving tension in the belt which operates

the pump tends to rotate the housing in the same manner as does the internal friction of the discs; this makes a calibration to determine power used by the oil pump unnecessary (See Fig. 3).

13 When the dynamometer is in use, water passes through the chambers of the housing and between the several units of plates and discs, and by its pressure tends to force the plates against the sides of the revolving discs. This pressure increases the friction between the discs and plates, and this friction offers resistance to the rotation of the discs. The construction resembles that of a constantly slipping friction disc clutch. The resistance to turning imposed by the friction plates and discs is balanced by the weighing apparatus.

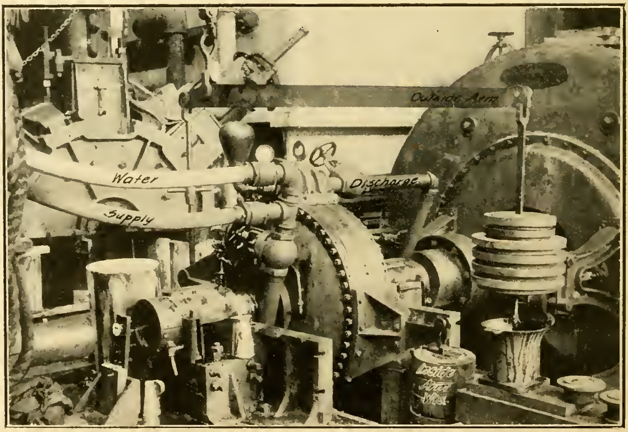

Fig. 4 Method of Counterbalancing Under Load

14 The power transmitted from the wheel under test tends to rotate the housing. This tendency is counteracted by the dead weights or a platform scales, and the housing is kept from rotating, beyond prescribed limits, by stops on either side of a lever arm bolted to the housing. The weighing apparatus by which the power absorbed is measured is delicately adjusted on knife-edge bearings. There are two sets of lever scales, which may be called the outside and inside scales. The outside indicates 1 h.p. for 1 lb. weight per 100 r.p.m. The inside scale indicates 1 h.p. for 10 lb. weight per 100 r.p.m. The outside scale serves not only to assist in balancing

the load—that is, to weigh it—but also to take the weight of the housings from the bearings on the hub of the revolving discs. (See Fig. 3 and Fig. 5.)

15 It is possible to take from the bearings not only the weight of the dynamometer, but also the weight of the shaft. There have recently been made several tests on wheels developing over 2000 h.p., where the entire weight of the dynamometer and shaft (about 13,000 lb. total) was counterbalanced so nicely that the nearest required running bearing was that of the water wheel some seven feet away from the dynamometer. In other words, when the load was on the

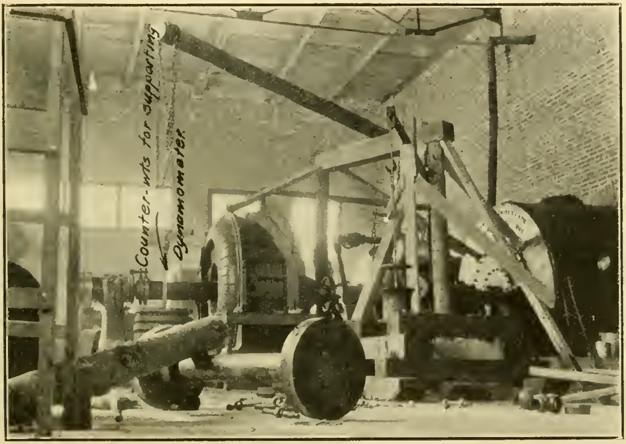

FIG. 5 AUXILIARY METHOD OF COUNTERWEIGHTING UNDER LOAD

dynamometer, it was as if it were placed on an overhanging shaft about seven feet from the nearest bearing. This point is an interesting one in mechanics, and shows that the wheels tested in place can be given a fair treatment under test, in that no additional load due to the weight of the dynamometer is put upon the wheel bearings.

16 To calibrate the dynamometer requires simply the determination of the distance from the center of the shaft to the knife edge bearing of the lever rod, and the ratio of the overhead lever; and the standardization of the dead weight, if used directly, or of the platform scales. Besides this, it is necessary to determine the initial load on

the dynamometer due to the unbalanced effect of the piping, fittings, arms, stops, lever and scale pan. This should be done at the time of test and with the apparatus as used. The usual method employed (shown in Fig. 7) consists in disconnecting the shaft coupling and raising the dynamometer so that parallel irons can be placed under the shaft; by means of a strut under the knife edge on the end of the lever the correct weight of the initial load is then obtained by the use of platform scales.

17 The largest dynamometer built at present consists of four 60-in. discs and has a power-absorbing capacity of 1500 h.p. at 100 r.p.m., or about 3000 h.p. at 200 r.p.m.

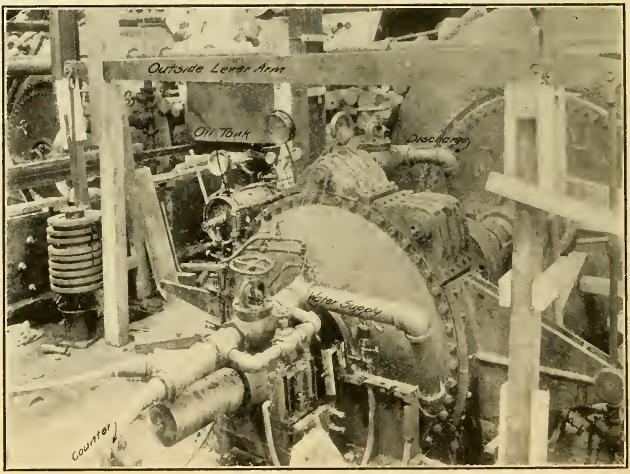

Fig. 6 Dynamometer Rigged for Testing

18 The capacity of the dynamometer is limited by the amount of heat that can be transmitted through the copper plates. This depends upon the range of temperatures and the amount of the circulating cooling water. The capacity is also affected by the kind of lubricating oil used. A cheap grade of cylinder oil has been found satisfactory. A system of forced lubrication is essential to smooth operation.

19 A series of tests has recently been made at the laboratories of the Worcester Polytechnic Institute to determine the relative heat-transmitting properties of copper sheets just as they are received from the rolling mill, and similar sheets electro-copper-plated. These tests were made with a view to increasing the capacity of the dynamometer. The apparatus used consisted of two double-disc Alden dynamometers with the rotating cast-iron discs removed. (See Fig. 8). The dynamometers as tested consisted of an outside cast-iron casing and four copper sheets, with the necessary spacing rings. The dynamometers were identical in every way, except that in one the copper sheets were electro-copper-plated.

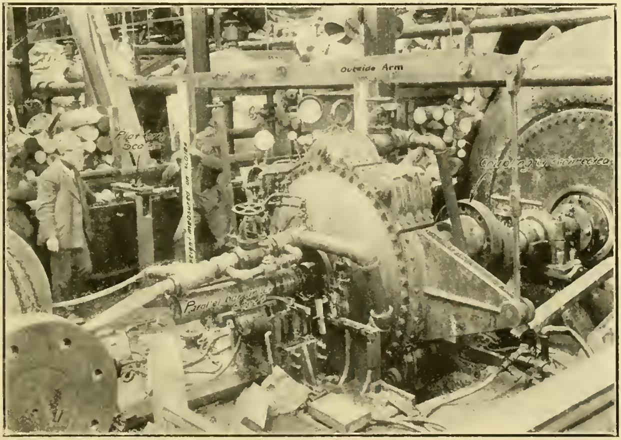

Fig. 7 Method of Calibration After Tests

COUPLING DISCONNECTED, SHAFT RESTING ON PARALLEL BARS, UNBALANCED LOAD OF DYNAMOMETER WEIGHED ON SCALES.

20 The dynamometers were set up so that the spaces normally occupied by the revolving discs were piped to the steam main. Plugs were removed from the top and bottom of these spaces so that all air and condensed steam would be removed. Circulating water was supplied at the bottom of the casings and taken out at the top, both the circulating water and condensed steam being collected and weighed. Thermometers were inserted in the steam line next to the dynamometers and in the water supply line, also in the discharge of

the circulating water and of the condensed steam. Several tests were run on each, of five minutes' duration. The accompanying table gives results of these tests.

	Plain Copper Sheets	Electro-plated Copper Sheets
Average temperature of entering circulating water.	44 deg. fahr.	44 deg. fahr.
Average temperature of exhaust circulating water.	100 deg. fahr.	100 deg. fahr.
B. t. u. per sq. ft. per min. per 50 deg. difference in temperature of circulating water.......	467	610
Increase, in percentage........................	...	30.8

21 The results were all reduced to a common basis, namely: the B.t.u. transmitted through 1 sq. ft. of copper sheet per min. per 50 deg. difference in temperature of circulating water. The dynamometer containing the copper-plated sheets showed an increased heat transmission of more than 30 per cent over the untreated. A probable explanation of this phenomenon is that when the sheets are electro-copper-plated, the copper is deposited in small globules and the actual surface not only is increased but is made rougher; this tends to mix up the water currents, bringing more new water in contact with the copper.

22 In the actual operation of these dynamometers, the heat is generated on a thin film of oil directly against one side of the copper and the water passes over the surface on the other side, carrying off the heat generated. It is a well known fact that more heat is transmitted through copper than can be readily carried off by the water, and any increase in surface in contact with the water gives a corresponding increase in capacity. As the capacity of these dynamometers depends upon the heat-transmitting power of the copper sheets, it is clear that this capacity can be increased 30 per cent by the use of electro-plated sheets.

23 Owing to the system of continuous forced lubrication, the dynamometers are capable of holding their maximum load for any length of time. A dynamometer recently used held a load of from 2000 to 2300 h.p. during a series of tests on a pair of turbines of over eight hours' continuous running. The reason for making so long a run was that the weir for measuring the water used was situated in the canal above the turbines, and considerable time was required to allow conditions to become constant. It may be of interest to note that this weir was standard, with end contractions, and was

73 ft. long. During the tests, when the wheel gates were wide open, the quantity used by the wheels required a head of 2 ft. on the crest of this weir. Long runs are also required when the current meter is used in measuring the discharge from the wheels.

24 The largest power ever absorbed at one time by these dynamometers was 4100 h.p., developed by a pair of turbines under a head of 110 ft. at a speed of 225 r.p.m. These turbines were used to furnish power for a paper pulp mill. There were six grinders on either side of the turbines, making twelve in all. The grindstones nearest the turbines were removed, and two dynamometers put in their places.

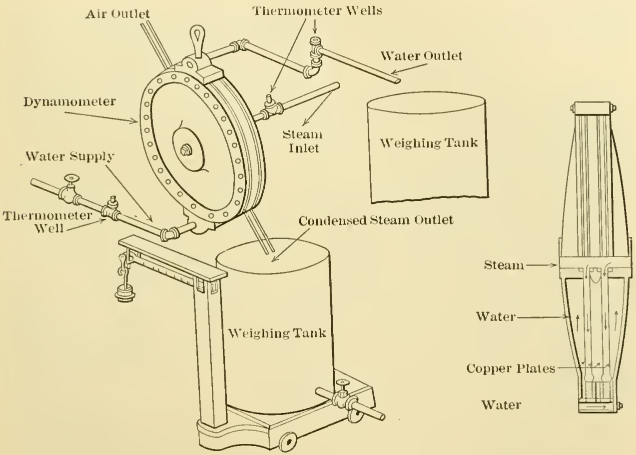

Fig. 8 Layout of Apparatus; with Section of Dynamometer

25 The amount of work required to make such tests is comparatively small, when the amount of power measured is considered. Two units of approximately 4000 h.p. were tested inside of three days.

26 In pulp mills it is difficult to know how much power the wheels are developing. It is not always safe to base the estimate on quantity of pulp, as there are many variations in the conditions of stones, wood, etc. Hence quite a large percentage of brake testing of wheels has been done in grinder rooms.

27 Several tests of large powers have been made in hydro-electric stations in which case the generators are set aside and the dynamometer mounted on the wheel shaft, usually in place of the half coupling.

28 To give an idea of the actual running conditions sometimes found, a test in one plant showed that the wheels were giving the power called for by the contract, but that if they had been run at 200 instead of 225 r.p.m., the power would have been increased from 2000 to 2300 h.p.; thus showing a waste of 300 h.p. and a correspondingly lessened efficiency. On another test it was found, that when the wheels were running at the guaranteed speed, the power and efficiency were between 30 per cent and 40 per cent lower than they should have been. Removing the entire load only slightly increased the speed.

29 Many tests have been made which show that if the wheels are given a "fair setting," and the speed properly chosen, they will agree closely with the computed ratings made from the tests at the Holyoke flume. One test of a pair of wheels, made after installation, agreed so closely with the computed results from the Holyoke tests of the individual wheels, that the curves showing the relation of the horsepower and efficiency to the speed-gate opening of the pair came between the curves of the separate wheels transferred to the same head basis. The term "fair setting" means that the water should be brought to the wheel with a low velocity; the draft tube should be designed especially for the particular conditions, and should be air-tight; the wheels, if a pair, and center-discharging, should not be set too closely together; if a pair and outward-discharging, end supply should be avoided if a steel penstock is used; the shaft of the wheel should not be larger than necessary; the bearings should be kept in line, etc. The setting just described refers to open flumes or steel penstocks and not to spiral casings.

30 Incidental to the brake testing of water wheels, considerable information has been obtained regarding the efficiency of large bevel gears, such as are commonly used in transmitting power from vertical wheels in low-head installations. About a year ago, a series of tests were made to determine: first, the horsepower delivered to the horizontal generator shaft from two vertical wheels; second, the horse power of the individual vertical wheels. By subtracting the former from the sum of the latter, the loss due to the bevel gears and bearings was obtained. The tests were conducted in the above order so as to get the ouptut at the generator coupling with gears running normally. Then the gears were removed and the individual vertical tests made.

31 The total horsepower delivered to the generator was approximately 700. (See Fig. 9 and Fig. 10). The driving gear was of the

ordinary wood-mortise type, outside diameter 6 ft. 5 in. approximately, with 68 teeth, 14 in. wide, meshing with a cast-iron pinion which had 48 teeth with a planed tooth outline. At full load the loss in the gears was 3.5 per cent and 3.4 per cent for two separate units, or the efficiency of the horizontal-shaft vertical-wheel gear drive was about 96.5 per cent. The gears were well lubricated with a thick grease.

32 About nine months later it was necessary to test one of these same units in exactly the same manner. The loss in gears this time was a trifle less, the tests giving 3.1 per cent. As a matter of fact,

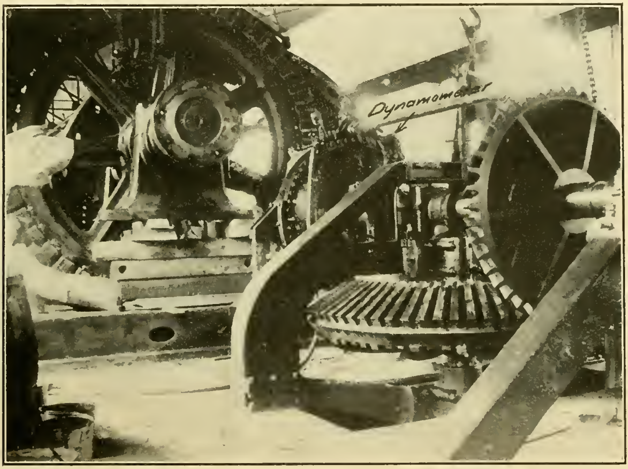

Fig. 9 Horizontal Testing of Vertical Wheels with Bevel Gears

the gears were running smoother at the last test, having had nine months more of service. When the first tests were made, the plant had been running less than a year.

33 Besides this direct measurement of gear efficiencies, two separate tests have been made within the past year, of two vertical Boyden wheels with the power measurements made on the horizontal shaft. These wheels had been in operation for over thirty years. The bevel gears (both the driving and the driven) were of cast iron in each unit. No brake tests were made on the vertical-wheel shafts but

the discharge from each was carefully measured over a standard weir by Mr. A. F. Sickman, hydraulic engineer for the Holyoke Water Power Company. The best efficiency of the wheels at full gate, which in this case includes the loss of gears and bearings, was 83.5 per cent and 83.7 per cent, respectively.

34 Several similar tests have been made with corresponding evidence as to good efficiency of the gears. In one plant, containing seven pairs of vertical wheels, where all the mortised wooden gears and cast-iron pinions had been in use for over fifteen years these were still good, without having had even a tooth changed.

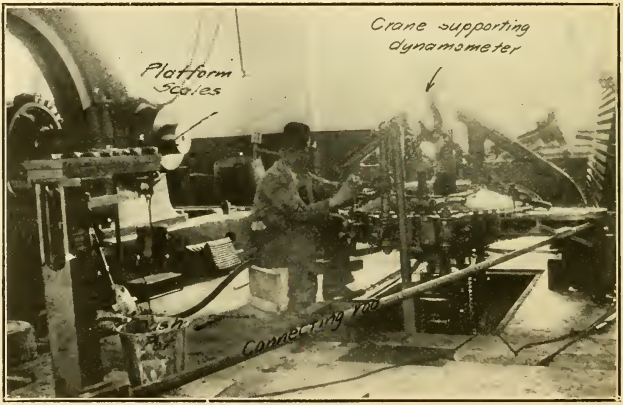

FIG. 10 TESTING OF VERTICAL WHEEL (GEAR REMOVED)

35 All of the information obtained concerning the loss due to bevel gear drives, leads the writer to conclude that if gears are properly designed, set up, and operated, and are not overloaded intermittently or continuously or left to care for themselves, they should show an efficiency of from 95 to 97 per cent.

36 Figs. 11 and 12 show two settings in which the wheels were tested after installation. The results of the tests, together with the results of the tests on the same wheels at the Holyoke testing flume, and reduced to a common head-basis, are given in the curves, Figs. 13 to 16 inclusive.

37 The setting shown in Fig. 11 is for a pair of 36-in. wheels operating under a head of 28 ft. at a speed of 200 r.p.m. The wheels are

set 3.3 diameters apart and the draft tube changes from a circular to an oval cross section with a constantly increasing area, and discharges horizontally into tail-race. In this particular installation, the velocity of the departing water from the draft tube was found to increase materially the working head on the wheels. The results of the brake tests made after installation, as shown by the accompanying curves, checked with the Holyoke tests computed for the same head at full gate. It may also be of interest to note that the generator tests made immediately following also checked with the brake tests. The difference between the two tests as shown in the curves at part gate openings is probably due to different methods of setting the gates under test. The full gate opening, however, was exactly alike in both cases.

38 In the setting shown in Fig. 12 the wheels actually give a considerable increase in power over that computed from the Holyoke tests. This is probably due to two reasons, the first and most important being that the Holyoke testing flume is not designed to test wheels of this size; and second, that the setting is exceptionally good. The wheels are 48 in. in diameter and are set 4.25 diameters apart with ample space around the wheels in the casing and with well-proportioned center case and draft tube. The curves in Fig. 15 and Fig. 16, representing the results of tests made on these wheels both at Holyoke and after installation, show that the best speed at full gate as computed from the Holyoke tests is about 182 r.p.m., and the best speed after installation 195 r.p.m. Comparison of the horsepowers at best speed shows an increase after installation of 40 h.p., but if the horsepowers at 195 r.p.m. be compared, then there is an increase of 130 h.p. This apparently excessive increase in power is to a large extent due to the fact that the best speed after installation was 195 r.p.m., while from the curve of the Holyoke test the power at 195 r.p.m. has materially dropped off.

39 The curves in Fig. 17 and Fig. 18 show the results of tests on a pair of 45-in. wheels under a head of 44 ft., with a normal speed of 200 r.p.m. It is seen that the discharge increases with the gate opening but the power begins to drop off at 0.75 gate opening and remains contant from 0.9 to full, which accounts for the efficiency curve dropping off so rapidly. In this installation the wheels were set too closely together (less than three diameters apart) and the shaft was excessively large. In accordance with data obtained from our recent tests these wheels should have been set at least four diameters apart.

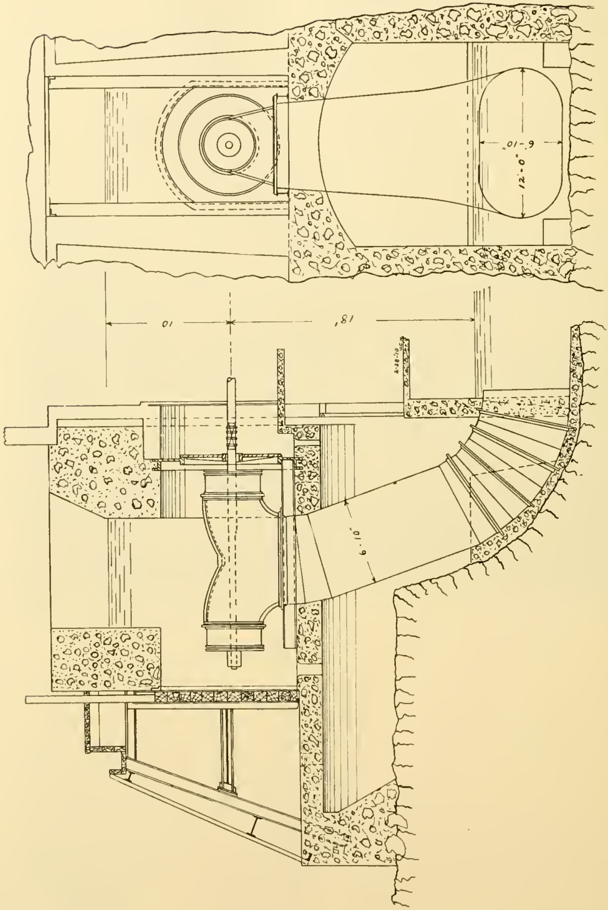

FIG. 11 SETTING OF A PAIR OF 36-IN. WHEELS UNDER 28-FT. HEAD. DISTANCE BETWEEN WHEELS 3.3 DIAMETERS

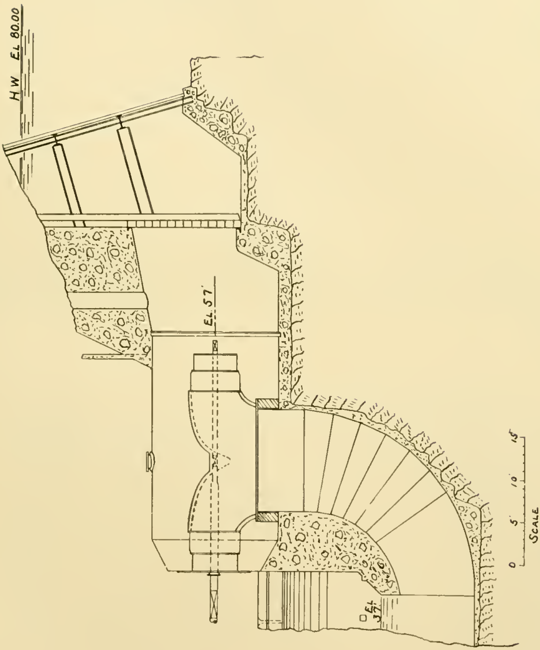

Fig. 12 Setting of a Pair of 48-in. Wheels under 40-ft. Head. Distance Between Wheels 4.25 Diameters

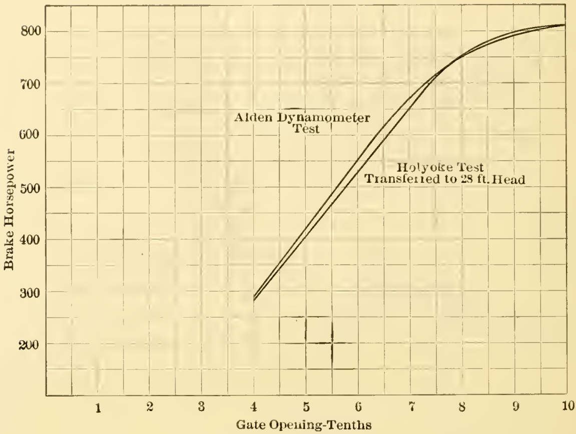

FIG. 13 CURVES SHOWING RELATION BETWEEN HORSEPOWER AND GATE OPENING FOR A PAIR OF 36-IN. WHEELS UNDER 28-FT. HEAD AND 200 R.P.M.

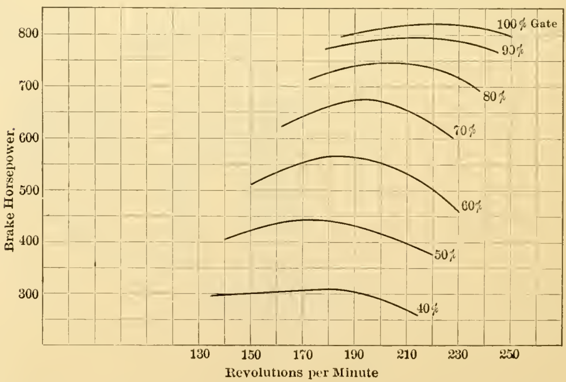

FIG. 14 CURVES SHOWING RELATION BETWEEN HORSEPOWER AND SPEED FOR A PAIR OF 36-IN. WHEELS UNDER 28-FT. HEAD

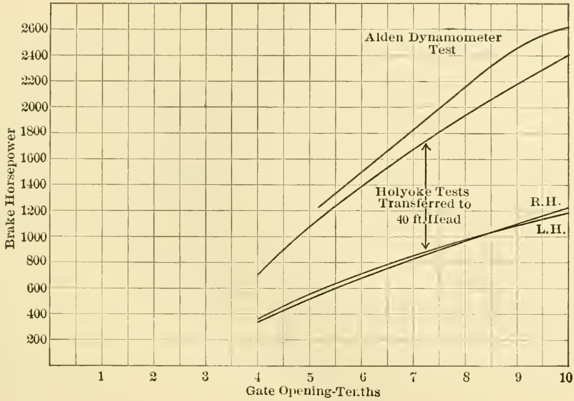

Fig. 15 Curves Showing Relation Between Horsepower and Gate Opening for a Pair of 48-in. Wheels under 40-ft. Head and 200 r.p.m.

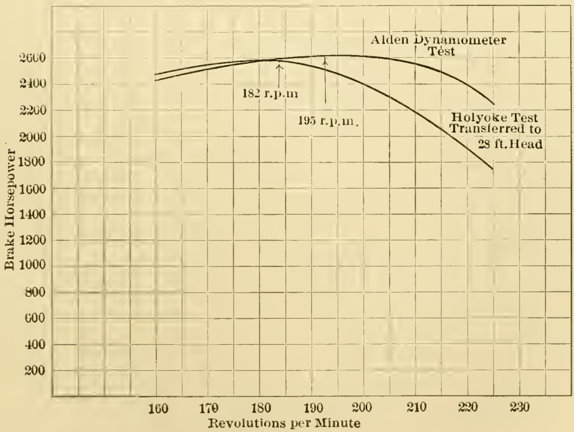

Fig. 16 Curves Showing Relation Between Horsepower and Speed at Full Gate For a Pair of 48-in. Wheels under 40-ft. Head.

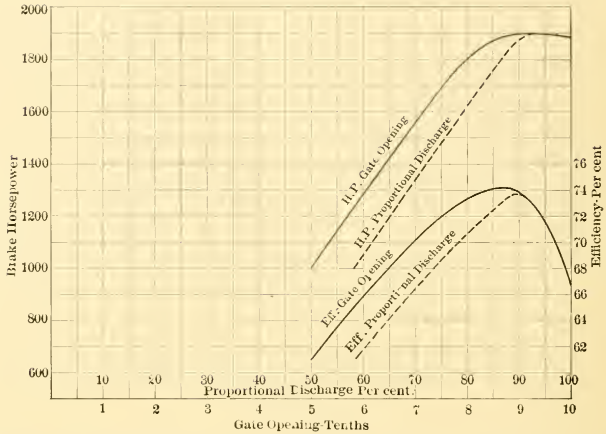

Fig. 17 Curves Showing Relation Between Horsepower and Gate Opening, Horsepower and Proportional Discharge, Efficiency and Gate Opening, Efficiency and Proportional Discharge; Pair of 45-in. Wheels, 44-ft. Head and 200 r.p.m.

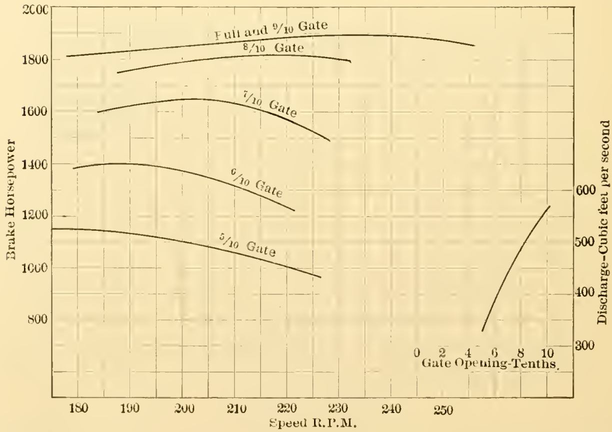

Fig. 18 Curves Showing Relation Between Horsepower and Speed, Gate Opening and Discharge; Pair of 45-in. Wheels, 44-ft. Head

40 While the tests on the 48-in. wheels shown in Fig. 12 are the best example that we have of large turbines actually showing more power when tested after installation than that computed from the Holyoke tests, it is by no means the only instance of such results. Within the past five years there have been made over 100 complete brake tests of wheels at different plants in all of the New England States and most of the Eastern Atlantic States. Most of the leading makes of wheels have been tested in this manner, and under heads varying from 10 ft. to 200 ft. Information derived from this experience confirms the following general statement:

41 That the performance of low-head turbines of diameters up to about 36 in., as computed from the Holyoke tests, should be attained after installation; that turbines greater than 36 in. in diameter should show better results after installation than those computed from the Holyoke tests, the amount of difference increasing with the diameter of the turbine.

42 There is still a vast deal of information needed concerning the behavior and proper settings of wheels after installation, before the subject can be put upon a good working basis, and it is hoped that enough points have been touched upon in this paper to call forth a goodly amount of discussion and reliable information that may be of value.

MECHANICAL FEATURES OF ELECTRIC DRIVING IN MACHINE SHOPS

By John Riddell, Schenectady, N. Y.
Member of the Society

It is with the mechanical features of motor driving that this paper is to deal, and chiefly with what has been done in the electrical equipment of the most commonly used machine tools in the plant of the General Electric Company, at Schenectady, with a few sketches of some large work that has been erected outside.

2 Some ten or twelve years ago it was decided to erect a large and up-to-date electrically driven machine shop, and plans were started some time ahead of the completion of the building. At first the plan was to have every machine tool individually driven, but the time was so short that we abandoned this idea and concluded to arrange the machines in groups, driven by a motor direct-coupled to the end of a section of lineshaft. This arrangement was used only to take care of small and medium-sized machines, of which few, if any, were at that time equipped with individual motors.

3 Considerable difficulty was experienced in arranging the lineshafts and countershafts in this system, owing to their being traversed by small side-bay electric cranes. Fig. 1 gives a general idea of this method of group-driving. However crude it may appear in the light of present practice, it was considered in its time thoroughly up-to-date.

4 One of the mechanical difficulties encountered in attaching individual motors to small machines was the unwieldy size of some of the earlier motors of small capacity. Sometimes the motor would be as large or larger than the machine and this feature was largely responsible for the prevalence of group-driving of small machines, even where the individual drive would have been preferred. Recent improvement in motor design has led to a great reduction in the size of motors for a given capacity, so that the 25-h.p. motor of today is not nearly so

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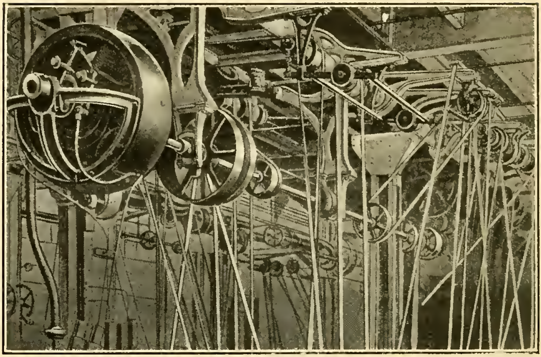

FIG. 1 METHOD OF GROUP-DRIVING

large as the 10-h.p. motor of earlier years. It is therefore much easier now to make the motor an integral part of the machine; and even where only fractional parts of a horsepower are required, for light operations,

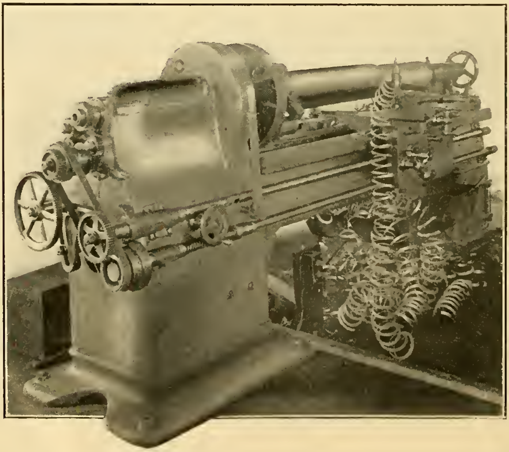

FIG. 2 LATHE DRIVEN BY INDUCTION MOTOR CONCEALED IN CABINET LEG

suitable motors of very small weight are now available which are well adapted in size to the smallest tools.

SMALL MACHINE TOOLS

5 Figs. 2, 3 and 4 show good examples of individual motor drives, in which the motors are inconspicuous and form integral parts of the machine tools. Fig. 2 shows a lathe driven by an induction motor concealed in the cabinet leg. Fig. 3 illustrates a wood-boring machine driven by an induction motor through a single pair of bevel gears. The inverted motor is bolted to a plate, which is in turn bolted to the

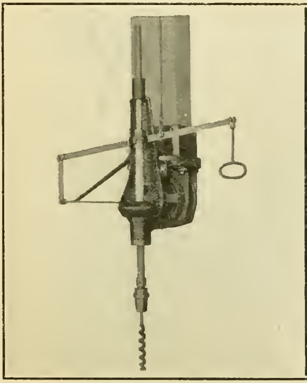

Fig. 3 Wood-Boring Machine Driven by Induction Motor, Through Single Pair of Bevel Gears

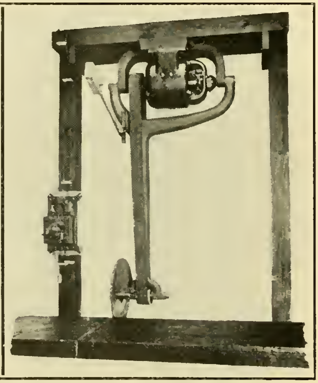

Fig. 4 24-in. Reliance Swing Saw with Motor

bottom of a post and to the frame of the tool. At first, the plate was arranged to swivel on the tool post, in order to provide means for moving the tool longitudinally over the work; but later, this adjustment was abandoned, as it proved to be easier to move the work horizontally with reference to the tool. This tool is a good example of the compactness of the electric motor, and its easy adaptability to wood-working machinery. Fig. 4 shows the application of a direct-current motor to a 24-in. swing saw.

LARGE MACHINE TOOLS

6 The large lathes, vertical boring mills, planers, milling machines, etc., were supplied each with its own individual motor, which was a marked improvement over the original belt-and-countershaft methods of driving. Since starting this work, the company has changed over several thousand machine tools to motor drives. Most of the difficulties in changing from belt to motor driving were in making suitable

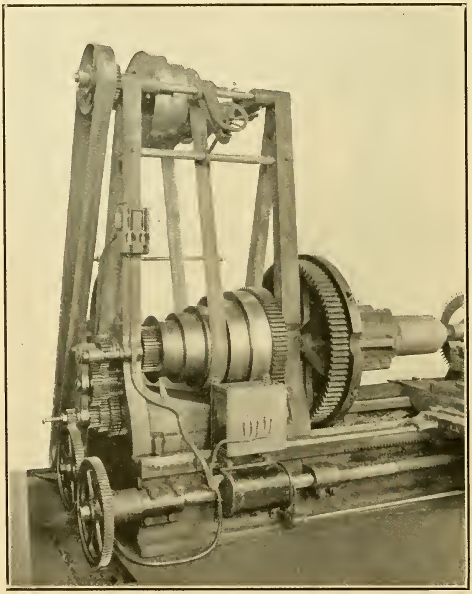

FIG. 5 42-IN. MILES-BEMENT LATHE DRIVEN BY CONSTANT-SPEED MOTOR USING CONES AND BELTS

connections between the motor and the tool to be driven. We do not pretend that in every case we have adopted the best arrangement, as in many cases the machine tool is not of sufficient value to warrant an expensive mechanical connection.

7 Take, for example, a medium-sized lathe of relatively moderate value. If an expensive transmission device was required in order to apply a motor to the lathe, the total cost of the lathe, as changed, might easily be more than the price of a new lathe especially designed for motor driving. In such cases it is found expedient to erect the countershaft and cone about four feet above the headstock, on suitable brackets, fasten the motor in a convenient place on the machine, and continue the use of cones and belts. Such an arrangement is shown in Fig. 5.

8 In all cases where old machine tools are converted to electric driving, it is desirable to mount the motor on some part of the machine

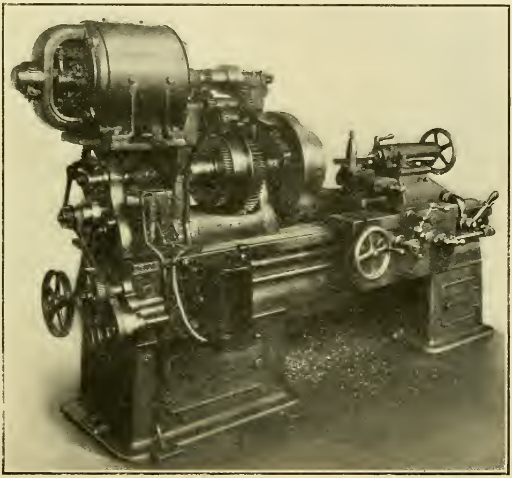

FIG. 6 24-IN. FITCHBURG LATHE DRIVEN BY MOTOR, WITH REVERSING GEARS

if possible, rather than on the floor near the machine. In the former case, the machine tool constitutes an independent self-contained unit which can be moved by the crane as a whole and located wherever desired. Cleanliness is promoted, by leaving a clear floor space to sweep, and the motor is less liable to accumulations of dirt caused by sweeping. There is also a tendency for the motor and the machine tool to become shifted out of alignment, if they are separately mounted on the floor.

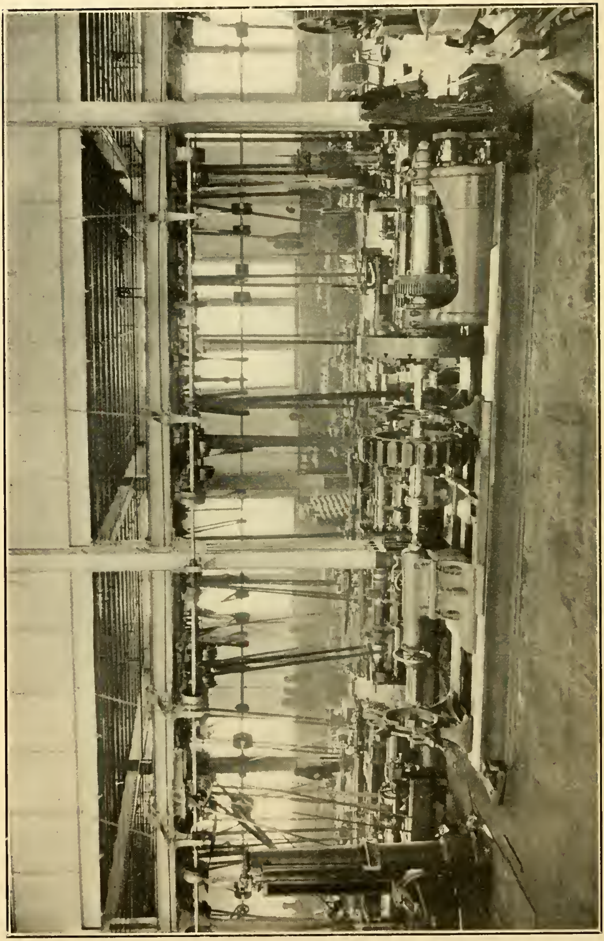

FIG. 7 LATHE, WITH MOTOR IN HEADSTOCK BENEATH SPINDLE

9 For lathes of more importance, and where the value of the tool warrants, we make an all-gear drive, with reversing gears, which are used principally for screw cutting. Fig. 6 shows a lathe equipped with reversing gears. More recently we have produced motors which can be very quickly reversed, obviating the necessity of reversing-gears.

10 When the original change was made from belt to motor drive there was one particular triple-geared lathe, 72-in. swing, to which we applied a two-to-one variable speed motor. The only change necessary in this case was to substitute two gears for the lathe cone, mounted on a quill, and made to engage with a pair of rocking gears on the motor. This gave a speed variation of four to one at the motor, and with the triple gears of the lathe, we had an exceedingly fine speed range. This lathe is shown in the foreground of Fig. 7. The motor is

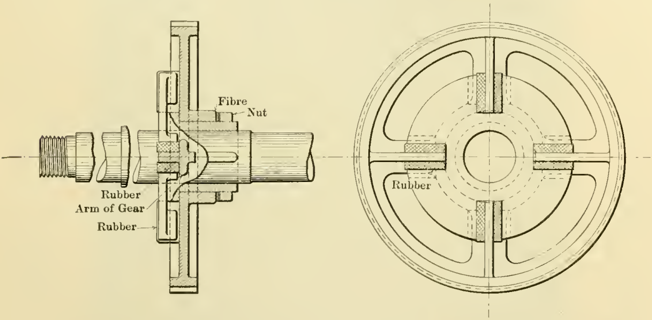

Fig. 8 Diagram of Device to Obviate Chatter Marks on Finished Work

placed in a most advantageous position, in the headstock underneath the spindle. During about ten years' service it has never been removed.

11 In a shafting department like that of the General Electric Company, where the range of size does not vary over three or four inches on the standard work, no very great speed changes are necessary, and a two-to-one motor usually has range enough to meet all requirements. What is particularly needed is ample power, strength of parts, and simplicity of construction, especially in lathes used for roughing, which are usually handled by unskilled labor.

12 For finishing shafts, however, where greater accuracy is required, an all-gear drive with steel gears is not satisfactory, because the chattering set up by the action of the gear teeth is very apt to be trans-

mitted to the finished work, leaving parallel ridges. This difficulty was overcome in some special lathes which we had built for the purpose, in which the driving gear on the main spindle was left loose and acted on the driving plate, keyed to the spindle, through four rubber buffers. This device is shown in Fig. 8.

13 More recently, trouble from this same cause was experienced in one of our tool departments, and was corrected by the use of a pinion made of muslin. This pinion has several features which specially adapt it to motor-driven machine tools. It is practically noiseless and

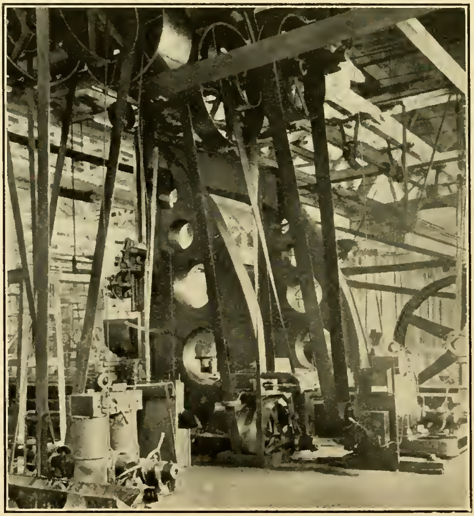

Fig. 9 Evolution of Application of Motors to Planers

LINESHAFT DISCARDED. COUNTERSHAFT DRIVEN FROM MOTOR ON FLOOR

very durable, does not shrink, and is sufficiently flexible and elastic to absorb vibrations which might be transmitted to the finished work.

14 Another application to motor driving in connection with lathes, and one that has been much appreciated, is the use of an auxiliary motor to operate lathe carriages having a long travel, of about 35 ft. The motor is bolted to one side of the carriage, and carries a pinion which meshes with the hand-wheel gear. A two-way switch is pro-

vided for operating the motor in either direction. The use of a motor not only saves the operator a difficult task, but it has also proved a great economy of time. It formerly required 30 to 35 minutes to shift the carriage through its full travel, and the hand wheels were placed so low that a man had to stoop to use them. The motor will move the carriage from one end of the lathe to the other in a minute and a half, and it can be stopped at any point within a 1/16 in. of the cut.

15 The best location for a motor on a lathe, and on most machine tools, is as low down on the machine as possible. The amplitude of the vibrations set up will be smaller, the closer the motor is to the floor, and the liability of chattering will therefore be reduced. The location of the motor in the cabinet leg, or in the headstock of a lathe, as shown in Fig. 2 and Fig. 7, is ideal, but there are, of course, many cases where the motor must be mounted over the headstock because no other place is available. The necessity of having the motor out of the way of the work is obvious, as turnings of chips, if allowed to get into the motor, would at once give rise to electrical troubles, especially in direct-current machines.

CONTROLLERS

16 The location and arrangement of controllers for lathes depend upon the class of work to be performed. Where the lathe is started, stopped, and varied in speed by the controller, the latter should be mounted on the front of the lathe, and the handle extended by means of a shaft to the lathe carriage, where it will be constantly under the hand of the operator. Ease of control unquestionably results in the rapid and economical production of work. Where the work varies considerably in diameter, frequent changes of speed will be required, and where the most efficient cutting speed can be obtained by simply turning a conveniently located handle, the work will be turned out at a maximum speed. If frequent shifting of belts is required, a great deal of the work will be done at less than maximum speed, owing to the extra exertion involved.

17 For lathes with constant-speed motors, operated with clutches and shifting levers, or machines on which continuous automatic operations are carried on, such as screw machines, the motor can be kept running for long periods without attention from the operator. In such cases the controller may be mounted at any convenient place on the machine, or near by on the floor, by means of a bracket.

PLANERS

18 Figs. 9, 10 and 11 illustrate the evolution of the application of motors to driving planers at the Schenectady shops. The first step, as shown in Fig. 9, was simply to discard the lineshaft and drive the countershaft from a motor placed on the floor. When this planer was operated by belts it was next to impossible to reverse it in a shorter space than about thirty inches, and even then with a great deal of wear and tear on the belts. Early in 1900 the company produced their first magnetic clutches for driving planers. The first of these clutches was applied to a Bement-Miles planer, 10 ft. wide by 20 ft. long. With this clutch, Fig. 10, we are able to reverse the planer prac-

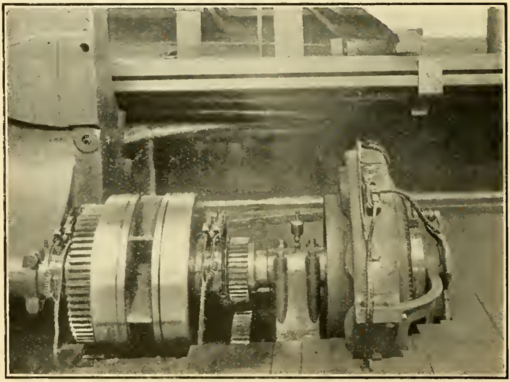

Fig. 10 Evolution of Application of Motors to Planers
MAGNETIC CLUTCH

tically to a line, and to reduce the space required for reversing to about 12 inches. Some trouble was experienced, however, with these first magnetic clutches, owing to the design of the magnets, and pneumatic clutches of a peculiar design were subsequently adopted and have been entirely satisfactory. Fig. 11 shows the arrangement of the motor and pneumatic clutch, as applied to the planer.

19 Our second lot of magnetic clutches was redesigned to eliminate the difficulties experienced with the first lot, and the new ones were applied to a number of portable slotters. These machines have been in continuous operation practically night and day up to the present

time. The clutches have operated with entire success, and I believe the magnetic clutch will eventually be found an important and efficient feature of transmission gears for planers and slotters.

VERTICAL BORING MILLS

20 In our original scheme for attaching motors direct to boring mills, an all-gear drive, with variable-speed motors, was selected, and with very slight changes, has been employed up to the present time. Fig. 12 shows a number of boring mills equipped in this way; the motors

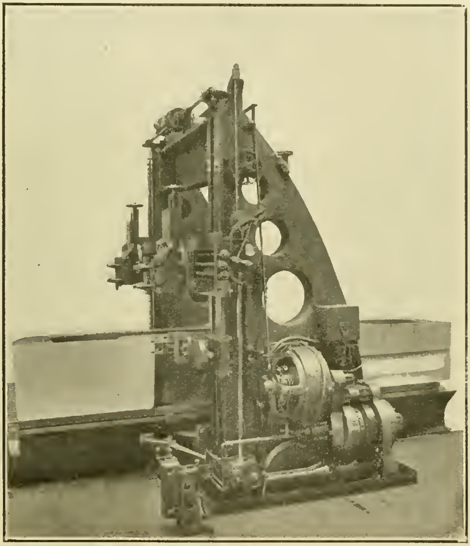

Fig. 11 Evolution of Application of Motors to Planers

COMPRESSED-AIR CLUTCH, TWO CONES

not being visible in the illustration because they are placed below the floor level between the side frames back of the revolving table. A solid foundation is laid, extending under the entire machine, a depression in the back between the side frames forming a bed for the motor, which is securely fixed in position. This common foundation makes the motor and the machine a single compact unit, and no additional

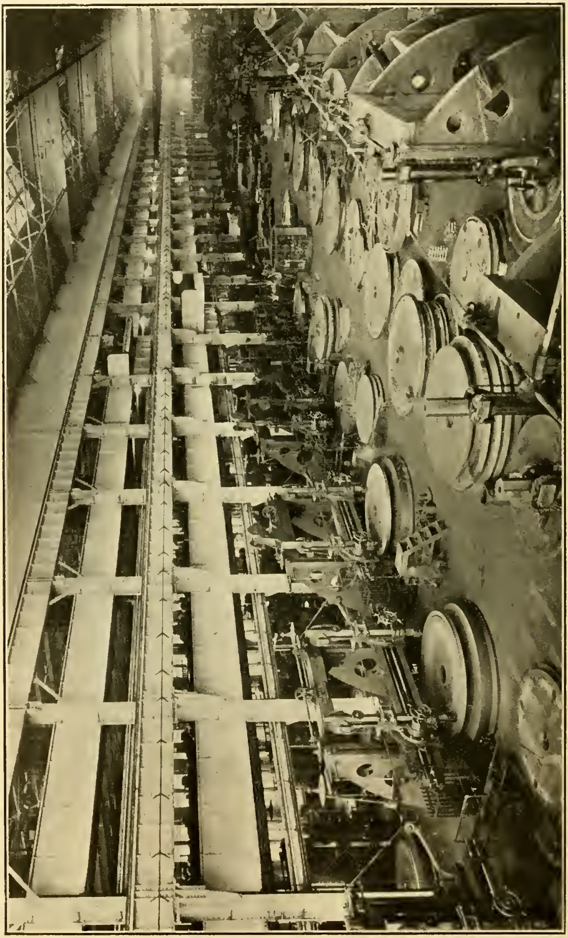

FIG. 12 INTERIOR VIEW OF BUILDING NO. 60

floor space is required for the motor. No work put upon the table can interfere with the motor, the gears are entirely out of sight, and the controller is placed at the right-hand side of the machine, where the operator usually stands.

21 On boring mills from 20 ft. to 25 ft. in diameter, with the usual slow intermediate and direct-gear drive that comes with the mill, a variable-speed motor of two-to-one ratio gives a very satisfactory speed range.

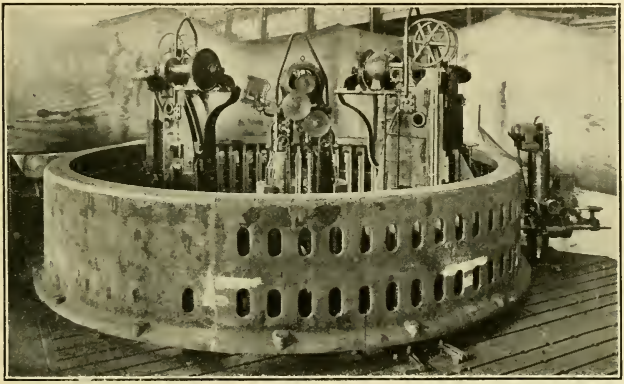

Fig. 13 Application of Motor to Machine Tools on Iron Floor Plate

PORTABLE TOOLS

22 Various machine tools of the portable type are used in ordinary large machine shops, and are placed in various positions on iron floor plates. The efficiency of these machines, such as rotary planers, slotters, etc., used in erecting departments, has been greatly increased by the use of electric motors. A group of these tools working on a large casting is shown in Fig. 13. The use of portable tools was almost impossible before the advent of the electric motor, but now the machine tools used in erecting shops, and in isolated places away from the source of power, when equipped with electric motors are ready to run at a moment's notice. On up-to-date rotary planers the motor is placed on the carriage; the under-side of the bases is planed, and means are provided for transfering the planers by electric cranes.

23 Under the old arrangement, if machinery stood idle for days and weeks, the countershafts and loose pulleys were so neglected that they would squeak; some one would then throw off the belts to stop the noise, and two hours' work was frequently necessary before they could be started for a hurried job. The same thing is true of some boiler makers' and blacksmiths' machines, such as rolls, shears, cutting-off machines, etc.

BELTING

24 Twenty-five or thirty years ago, in the days of the old jobbing shop, the buildings were not so high-studded, and the lineshafts and countershafts were usually within reach of a twelve-foot or fifteen-foot ladder at the most. Cone belts running to machine tools were very easily manipulated, and an expert lathe hand would never think of using a pole for shifting his belt from one step of the cone to another. But in these days of sanitary buildings, with ceilings from twenty to twenty-five feet high, it becomes an exceedingly difficult problem to arrange countershafts within reasonable heights; to say nothing of the necessary length of the vertical belts, the dust set in motion, and the difficulty of painting and whitewashing ceilings for the sake of cleanliness.

25 Another condition of lineshaft driving which has not been much spoken of, of late, is the difficulty of keeping the shaft in alignment, where the hangers are suspended from the roof trusses. The writer has seen such shafts five or six inches out of alignment, due to a heavy fall of snow on the roof, or to the settling of foundations. Another trouble is due to state laws and shop rulings, where a few trained men are employed as belt-lacers, and it is against the rules for men who are not belt-lacers to do the work. This is the cause of numerous delays, with consequent loss of production.

26 The only advantages that may be claimed for belts is that they take up the vibration of the gears, and thus prevent chatter marks on fine work; and that they will slip under over-load and be thrown off the pulley, stalling the machine, instead of breaking the tool or spoiling the work. It has already been explained how the effect of vibration has been remedied by means of rubber buffers or muslin pinions, and there are exceedingly few cases where belt-slip is not a detriment rather than an advantage. The use of high-speed tools calls for a considerable increase in the power necessary to drive the machines, as these tools take a heavier cut at a higher speed than those of car-

bon steel. These conditions make belt-slip very objectionable, and one of the chief advantages of motor driving is that it increases the power of machine tools beyond the capacity of belts of reasonable length. Modern practice is in the direction of eliminating the belt almost entirely, although there are a few machine tools, such as the older types of automatic-screw machines, grinding machines and some wood-working machines, on which they are necessarily retained.

27 The great majority of metal-working machines are best adapted to motor driving through all-gear connections, although a few machines, such as small grinders, buffing wheels, polishing wheels, etc., are best connected direct to the motor shaft.

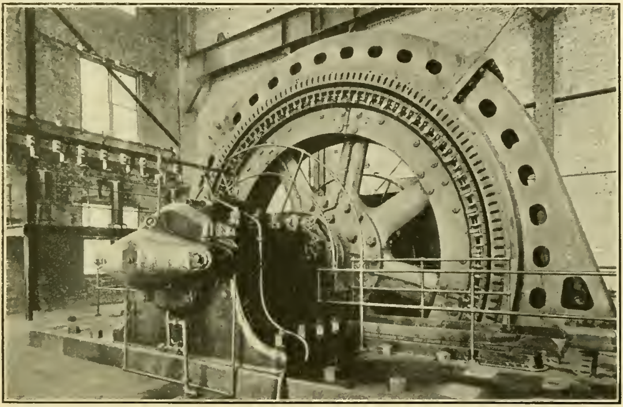

FIG. 14 6000-H.P. INDUCTION MOTOR, RAIL MILL, INDIANA STEEL COMPANY GARY, IND.

STEEL MILL WORK

28 The application of motors to metal-forming machines, such as rolls for rolling steel, charging cranes, etc., does not belong strictly to machine-shop practice, but the work of these machines is closely allied to what is required of other metal-working machines. Some of this work now performed by motors, is the heaviest kind of mechanical work ever attempted by any kind of prime mover. Fig. 14 shows a large induction motor driving an up-to-date steel rail mill, requiring 6000 h.p. or more. The operation of an entire mill is fre-

quently dependent on the continuity of operation of each piece of apparatus. For this reason it has been the practice to build the steam engines which drive mill machinery of the most substantial material and design. In replacing engines by electric motors, these same features were embodied in the motors.

29 The breakable coupling between the engine and the rolls is retained when motors are used. This coupling is of such strength that it breaks before the rolls are injured by shocks. The coupling frequently breaks diagonally, and a very heavy end-thrust is sometimes

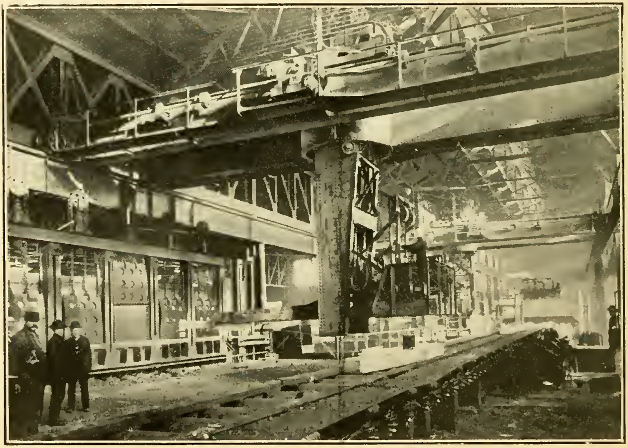

Fig. 15 Charging Crane, Blooming Mill, Illinois Steel Company, South Chicago, Ill.

produced, tending to separate the ends of the coupling. With the engine drive, this end-thrust frequently slides the roll housings out of their places, and considerable time is required to replace them. When motors are used, this difficulty is readily avoided by allowing the shaft of the motor to slide longitudinally in its bearings. To keep the motor shaft in its proper position, a breakable end-thrust bearing has been devised, which allows a bolt to break at a predetermined pressure before any other part of the machinery can be injured. This breakable bearing is shown in Fig. 14. It acts through the breakage of the long bolts shown alongside of the bearing housing.

The ready replacement of the parts when the coupling breaks is only one of the advantages incidental to the use of the motor for driving rolls.

30 Another style of motor, known as the mill motor, is illustrated in Fig. 15 and Fig. 16. It is used on slab-charging cranes, screw-downs, mill tables, etc., where it is subject to very rough handling, intense heat, severe over-loads, dirty surroundings, and other unfavorable conditions. All portions of these motors, such as the frame, shaft and bearings, are built unusually heavy to withstand safely the shocks to which they are subject.

31 There are thousands of other motor applications, which the writer will not attempt to describe. In the very complete paper by Mr. DeLeeuw, The Economy of the Electric Drive in the Machine Shop, are enumerated some of the important points in regard to apply-

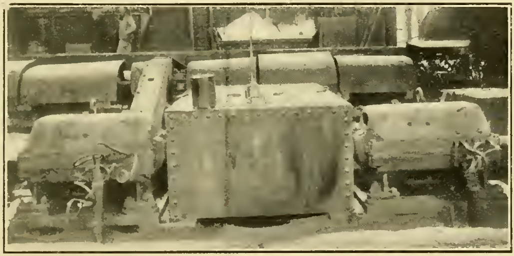

Fig. 16 Two 50-h.p. D.C. Motors

ing motors to machine tools. The writer has, therefore, endeavored to confine himself to a consideration of these mechanical features not already covered.

32 At the Schenectady plant alone we have running some 8500 machine tools, of which 8150 are individually motor-driven. Group-driving has been adopted for some sensitive drills, speed lathes, and other small miscellaneous machines. Of the above tools there are 48 portable machines, consisting of slotters, milling and drilling machines, radial drills, etc. These machines are operated on 32,675 sq. ft. of iron floor plate, in addition to which there are 7000 sq. ft. of iron rails, cemented into the floor, for erecting purposes.

33 Had we continued our extensions since 1899, using lineshafts, countershafts and belting, we would have approximately 34,570 ft. of lineshaft, or about 6½ miles, and about 4¾ miles of countershaft which would require about 21,225 hangers and bearings. Allowing two belts to each machine, with an average length of 25 ft. per belt, we would have for the 8500 machines a total of 425,000 ft. of belting, equal to about 80½ miles.

DISCUSSION

AN ELECTRIC GAS METER

By Prof. Carl C. Thomas, Published in The Journal for December 1909

ABSTRACT OF PAPER

This paper describes a meter for measuring the rate of flow of gas or air which can be adapted for use as a steam meter or as a steam calorimeter, taking the quality of all the steam passing through a pipe instead of that of a sample of steam. The operation of the gas meter depends upon the principle of adding electrically a known quantity of heat to the gas and determining the rate of flow by the rise in temperature of the gas (about 5 deg. Fahr.) between inlet and outlet. The meter consists of an electric heater formed of suitable resistance-material disposed across the gas passage so as to impart heat at a uniform rate to the gas. The resulting rise of temperature is measured and autographically recorded by means of two electrical-resistance thermometers, one on each side of the heater. These consist of resistance-wire wound upon metal tubes so placed that all the gas passing through the meter comes in close proximity to the thermometers. The adoption of this principle of operation permits the construction of a very accurate and sensitive autographic meter of large capacity containing no moving parts in the gas passage; it is independent of fluctuations in pressure and temperature of the gas and capable of measuring gas or air at either high or low pressures or temperatures. The electrical energy required is about 1 kw. per 50,000 cu. ft. hourly capacity, at the pressures ordinarily used in gas mains.

DISCUSSION

Prof. L. S. Marks. The meter described by Professor Thomas should prove a valuable addition to the instruments used in gas engine and other testing. The possibilities of error in the indications of such an instrument must be fully examined.

2 This meter is fundamentally an instrument for determining the weight of gas or vapor flowing through it and is made to record volumes. It is obvious that these volumes cannot be those actually flowing but must be the volumes reduced to some standard conditions of temperature and pressure. The author has not mentioned this matter in his paper, but it is of considerable importance. A variation of 5 deg. fahr. in temperature, or of 0.3 lb. in pressure, under ordinary

atmospheric conditions, would result in an error of 1 per cent in the indications of the instrument if it were assumed to record actual volumes flowing. The calibration of the instrument by passing through it a known volume of a gas at known pressure and temperature, can easily be reduced to a calibration under standard pressure and temperature conditions.

3 In Par. 16 the author refers to the effect of water vapor carried in with the gas. He states that, in consequence of the small rise of temperature, the water vapor does not experience a change of state, and that, consequently, the latent heat of vaporization does not enter into consideration. It is obvious that he is considering here the case of a gas which not only is saturated with water vapor, but also is bringing with it minute particles of water in suspension. Under these conditions—and they are conditions which may easily obtain with blast-furnace gas which has just passed through the washers—the indications of the instrument will be rendered completely useless.

4 If the gas should enter at a temperature of 70 deg. fahr. it would contain 0.001148 lb. of water vapor. After passing through the meter with a rise of temperature of 5 deg. the same weight of gas could contain 0.001198 lb. of vapor; that is, there would occur a vaporization of 0.00005 lb. of moisture for every cubic foot of gas passing through the meter. The latent heat of vaporization at these temperatures is about 1050 B.t.u., or, 0.0525 B.t.u. will be used in converting the water into vapor. As the total heat required for raising one cubic foot of the gas 5 deg. fahr. is only about 0.1 B.t.u., we have here, obviously, the possibility of an error of the magnitude of 20 or 25 per cent in the indications of the instrument in the case suggested by the author where the gas is supersaturated with vapor.

5 The accuracy of the instrument depends primarily on the accuracy with which the volumetric specific heat of the gas can be determined, and upon the constancy of this quantity while the meter is in operation. For the correct determination of the volumetric specific heat it is necessary to know the volumetric composition of the gas and the volumetric specific heat of each of the constituents. The author has stated that the volumetric specific heat of each kind of gas is very nearly constant and the calibration of the instrument is based upon that assumption; that is, it is proposed to calibrate the instrument with, for example, producer gas, and then to use that calibration when the instrument is used at other times with producer gas. It will be interesting to examine how nearly correct this assumption

is. In the December number of The Journal of the Society there are given four analyses of producer gas, three of them by Mr. Bibbins, and one by Messrs. Garland and Kratz. I have worked out the volumetric specific heats of these gases, using the physical constants given by the author, and I have also taken at random two analyses from tests which I have made on a large anthracite gas producer. The results of the calculations are as follows:

6 For the two lignites in Mr. Bibbins' paper, the values of the specific heats are 0.01920 and 0.01899, which agree very closely with the average stated by the author. For the bituminous coal in Mr. Bibbins' paper, the value is 0.01899, and for the bituminous coal in the paper of Messrs. Garland and Kratz, the value is 0.0186. My own tests with anthracite give values 0.01826 and 0.01848, respectively.

7 It is quite evident from these figures that there is considerable variation, which may be as great as 5 per cent in the volumetric specific heat of producer gas. It may possibly be, as these figures seem to indicate, that the specific heat can be stated with greater accuracy if the type of coal is also specified, since there seems to be a relation between the volatile contents of the coal and the specific heat of the producer gas; but this point has not been sufficiently investigated to permit of any definite conclusions.

8 I have attempted also to see whether the value given for illuminating gas is constant. Only one illuminating gas was considered—that in Cambridge, Mass.—the analysis having been made by the chemist of the gas company. The specific heat calculated from this analysis is 0.02278. The specific heat calculated by the author is 0.02111. The value which he states as being practically constant for illuminating gas is 0.020. There is a variation of over 10 per cent between these values, so it would seem that it is not practicable to calibrate this instrument with illuminating gas at one place and assume it to be accurate when used with illuminating gas at some other place.

9 Moreover it must be recognized that such analysis as that given by the author for illuminating gas is only approximate; the heavy hydrocarbons are never fully analyzed and some kind of guess must be made as to their composition and specific heats. It cannot even be accepted as true that a calibration made with any particular illuminating gas will hold at some later date for gas from the same source. I have found variation in the composition of the Cambridge gas which would certainly cause a variation of two or three per cent in its specific heat.

10 It appears to me then, that this instrument cannot be accepted for accurate measurement unless analyses are being made of the gas that is going through the meter. In scientific testing, such analyses will naturally be undertaken and consequently the instrument should be extremely valuable in such cases. I would like to know what experience the author has had with this instrument in the measurement of volumes when the flow is variable as, for instance, when gas is flowing through a single-acting, four-cycle gas engine. In this case the flow will occur approximately for only one-fourth of the whole time of the test. The author's contention that the indication of the instrument would be accurate under these circumstances seems reasonable, but it would be valuable to know whether, and to what extent, his statement has been verified by actual investigation.

Prof. W. D. Ennis. I do not quite follow Professor Thomas' explanation that the proper correction has been made for fluctuations in the pressure of the gas. A change of, say, five per cent in the pressure, measured above the zero of pressure, would correspond roughly with a change of five per cent in the absolute temperature, without any addition whatever of heat. A change of five per cent in absolute temperature would mean a very large change in Fahrenheit temperature.

2 A more important point is suggested by the statement in Par. 4: "These thermometers consist of wire wound upon vertical tubes so disposed as to come in contact with all the gas passing through the meter, thereby indicating the average temperature over the cross section of the gas passage." If that is what the thermometers do, I question whether they indicate the average temperature of the gas, because more gas is passing at a point in the middle of the pipe than at points near the circumference. Do the thermometers indicate the average temperature of the whole weight of gas, which is the temperature that we must have in order to calculate the weight of gas flowing?

Edwin D. Dreyfus. Certain fuel gases—particularly blast-furnace, coke-oven and producer gas—carry with them a considerable quantity of finely divided solid matter, which in turn forms deposits in the piping or in any piece of apparatus through which the gas passes.

2 From their construction, it would seem that the grids in the meter would favor the formation of deposits of this sort, and I would like to ask whether Professor Thomas has made any trials to deter-

mine what effect, if any, such deposits have on the accuracy and general reliability of the instrument.

3 In cases where the gas is carried long distances through overhead mains—as in many blast-furnace plants—the temperature of the gas will be largely influenced by the temperature of the atmosphere, as between the summer and winter months the gas temperatures might easily vary as much as 50 deg., and the variation in temperature would have a decided effect on the moisture content. It seems probable that the moisture content of the gas is the most disturbing factor affecting the accuracy of the instrument. If this be so, then it is desirable that the actual significance of this factor should be determined by trials made over as wide a range of conditions as we may reasonably expect to meet in ordinary everyday practice.

A. R. Dodge. I would like to ask Professor Thomas if he has made calculations in regard to the amount of power necessary to operate this meter when used as a steam meter. The specific heat of steam being greater than that of gas and air, the amount of power required is considerable. For instance, Thomas meters on the large turbines of the New York Edison Co. would require about 545 kw. at normal load, quite a percentage of the total output of the turbine.

The Author. Bearing upon the questions asked in the discussion, I would say, that in addition to the description of the meter given in the paper, I have given in Fig. 10 completed curves[1] showing the results obtained in calibrating the meter with both illuminating gas and air, reduced to standard conditions of 29.9 in. mercury and 62 deg. fahr. These curves show the method of using the meter for measuring directly standard cubic feet of gas or air at some convenient assumed conditions of pressure and temperature. In Par. 14, line 7 should read ". . . . at mean atmospheric pressure and 60 deg. fahr. . . ." The calculations in the table are for conditions of 760 mm. and 0 deg. cent. The results of measurement by the method described in the paper may be considered as given either in standard cubic feet, or in weight of gas passing the meter.

2 These meters are essentially applicable to the measurement of a dry gas or steam, that is, a gas or steam which is either saturated or superheated. Our experience with the gas meters has thus far been with illuminating gas and with air, and these are exceedingly easy of measurement. The gas or air we are measuring is saturated,

[1] Addition to paper, published in The Journal for January, 1910.

carrying its full quota of water vapor. The smallest quantity of heat introduced causes an immediate rise in temperature of the gas. If the gas carried a spray or mist of water, the measurement would be in error to a certain extent, because of the difference in specific heat between the water vapor and the gas. The extent of the error would depend upon the percentage of water vapor present.

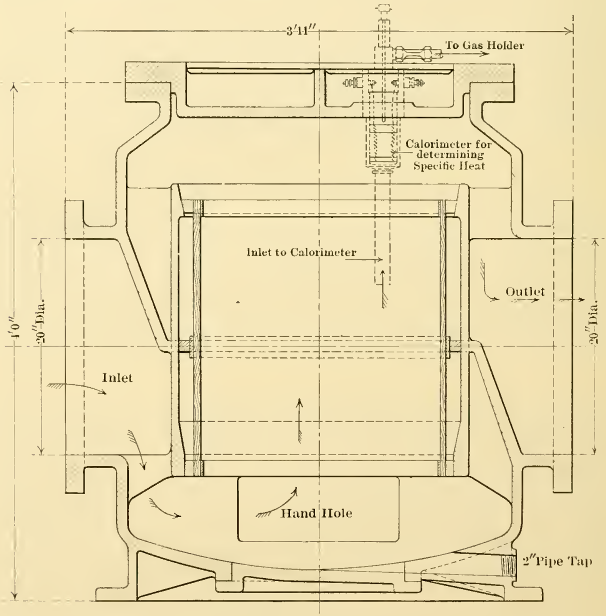

Fig. 1 Gas Meter arranged with Calorimeter for Determining Specific Heat

3 For gas or air under the conditions existing during the tests, of approximately 60 deg. fahr. and 29.8 in. mercury, and 6 in. water pressure, the correction for water vapor introduces a change in the results of less than ½ of 1 per cent, and has therefore been omitted. For other pressures and temperatures the correction for water vapor can be easily made by reference to the charts commonly used in gas works.

4 An interesting confirmation of the statement in Par. 16 is that the most minute addition of electrical energy to the gas or air causes an immediate rise of temperature.

5 Regarding variation of specific heat, the meter prover shown in Fig. 1, herewith, has been developed. It consists of a small electric heater which is placed in the outlet of the meter and discharges into a portable gas-holder such as is used for proving large meters. By this means a small known quantity of the gas is heated, and the specific heat actually determined by direct measurement. This determination can be made as often as desired until the variation of specific heat and satisfactory average values have been determined. So far it appears that the specific heat in a given installation is practically constant from day to day and from one time of day to another. The fact that it is possible thus to determine the specific heat experimentally affords a most valuable check upon the specific heat determined by calculation from chemical analysis, since the methods used in the latter are at best largely approximations.

6 As to dust and impurities collecting on the heater: A meter now in operation for some months has been used for measuring in the neighborhood of 100,000 cu. ft. per hr. of illuminating gas. The heater has been taken out once, and in handling it a small amount of grease was found on the heater material. Otherwise the interior of the meter was clean. In handling very impure gas it will of course be necessary to clean out the meter occasionally, simply in order to provide sufficient area for the passage of the required amount of gas. All the heat generated in the heater necessarily goes into the gas. The operation of heating and measuring difference of temperature is all accomplished in a very short length of travel of the gas. This perhaps answers the question regarding the heat-insulating effect of deposits which may be formed on the heater. The rise of temperature of the material of the heater is only 15 or 20 deg. fahr. This temperature rise might be effected by a considerable deposit on the heater, but the heat generated must necessarily be liberated from the heater and given up to the gas, resulting in no error in gas measurement.

7 As to variable flow, the best evidence is presented by the curves and calculations on the chart. The entire regularity of operation, during experiments conducted under circumstances very favorable to accuracy of observation seem to show that no error is introduced by non-uniformity of flow. If such a cause of error existed, it seems probable that it would have been found during experiments such as have been made with this meter, covering the wide range of from

6000 cu. ft. to about 127,500 cu. ft. per hr. The meter is now being built so that the gas passes in a vertical direction through the heater and thermometers, and this would seem to favor regularity of distribution over the cross section of the passage. The change from horizontal to vertical position was however dictated by convenience of attachment and in order to obtain accessibility, although it seems favorable to the above-mentioned consideration.

8 During the air tests extensive fluctuations of pressure took place, due to the pulsations of the blower supplying the air. These were so great at times as to cause the water to be thrown completely out of the pressure gages, but the results obtained remained entirely regular, as shown on the chart. A small meter has been used on a single-acting three-cylinder four-cycle gas engine delivering from 30 h.p. to 60 h.p. The meter was constructed of sheet iron, and although the pressure fluctuations were such that the sides of the heater "panted" continuously, the measurement of gas was accurately accomplished.

9 Answering Mr. Dodge's question regarding the amount of energy required to measure steam with these meters, we are using 5 deg. fahr. temperature difference, which can be measured to an accuracy of 1 per cent and the energy required is 1 kw. per 1000 lb. of steam per hr. Taking a water rate of 12 lb. per h.p.-hr., 1 kw. would measure the steam used for about 80 h.p.

10 Stated generally this meter seems to be particularly suitable for the measurement of dry saturated or superheated gas, air or steam. The substance to be measured should be dry, but it may be of any pressure and temperature which the materials of construction will stand, and the measurement is independent of fluctuations of pressure and temperature. The recording mechanism can be placed in any convenient position, as, for instance, in an office, instead of near the meter, and the graphical record is thus continually observable. It is not necessary that a graphical record should be taken. An ordinary integrating wattmeter showing the amount of energy it has required, to maintain the constant temperature difference of 5 deg. between inlet and outlet of the meter, suffices as a record of rate of flow, though the variation is best shown by an autographic record

GOVERNING ROLLING MILL ENGINES

By W. P. Caine, Published in The Journal for Mid-November

ABSTRACT OF PAPER

The paper describes first the types of rolling mills and the engines driving them; analyzes the distribution of power, the design and the peration of the engines, calling attention to causes of low steam economy, high repair charges and the danger of broken flywheels; describes and gives indicator cards and speed curves of a Corliss engine driving a three-high mill under two different conditions of governing, (*a*) under the widest range of adjustment of cut-off, (*b*) under a limited range, increasing the economy and making the engine run much more smoothly and safely. It also gives the reasons for the different results shown. A table is given showing the power required for rolling in the mill and the momentary source of the energy, whether from the cylinder or flywheel. A diagram shows this graphically. A description is also given of the tachometer used to take the speed curves.

DISCUSSION

Henry C. Ord. The conservation of energy as applied to rolling mills has received very little attention until during the past five or six years. The power required to roll a given piece was not known until the continuous indicator and recording tachometer were applied. The cards from these instruments furnished records from which the conditions for any stage of the operation could be calculated, giving complete information as to the variation in power and speed for different conditions and classes of work.

2 Rolling mill engineers have several reasons for preferring the two-high mill. As Mr. Caine says: "The engine uses steam only when the piece is on the mill." As there is considerable time between pieces in some classes of work, this is an important item. Should a piece not enter properly and stick in the rolls, thus stalling the engine, it is easy to reverse and back out the piece. This condition with a three-high mill would cause considerable trouble and delay. This is the reason why some of the modern three-high electric-motor-driven rolls are fitted with an emergency reversing de-

vice. The reversing feature can also be used as a quick safety-stop in case of accident.

3 The two-high mills are not so complicated as the three-high mills, and they have less rolls and no reversing mechanism for raising and lowering the table. In considering the two systems, this is an item of power that should be charged to the three-high mill. However, power is not the only consideration; it is usually a question of the maximum tonnage in minimum time with the least amount of power.

4 The 25,000 h.p. engine Mr. Caine refers to is a 42 in. and 70 in. by 54 in. twin tandem horizontal compound-condensing blooming-mill engine, designed by the writer about four years ago, and built by the Allis-Chalmers Company for a blooming mill requiring an average of about 6000 h.p., which is also about the economical load for the engine. It was designed for a maximum of 25,000 h.p. under the following conditions: steam pressure, 150 lb. gage; cut-off, $\frac{3}{4}$ stroke; vacuum 25 in. referred to 30 in. barometer; r.p.m. 200. This machine has been described as "the world's most powerful engine." I believe the piston speed, 1800 ft. per min., is the world's record.

5 If the engine Mr. Caine has experimented on was tested under the same conditions as regards pressure and work, with and without the function of the adjusting screw, we would expect different results than those shown. The controlling device has no control over the engine before the load is increased, until the speed falls to that fixed by the adjusting screw. At this speed and power the engine will be doing the maximum work allowed by the adjusting screw; consequently this control can be applied only to engines that have a longer-range cut-off than is required for the greatest loads they have to carry. After the above conditions are studied, it will be evident that to prevent the engine's being stalled before reaching the latest cut-off for which it was designed, we would have to dispense with the services of the adjusting screw.

6 From a study of the speed curves in Fig. 2, assuming that the height of the governor varies approximately as the speed of the engine, it will be seen that had the adjusting screw been applied and adjusted for the maximum load or minimum speed, it would be in momentary control during the second pass, and from the speed curves given in Fig. 3, it is seen that it was in action for about the same length of time during the third pass. As it would take considerable time for sufficient change in the energy of the flywheel to produce the results claimed, we believe there are other reasons for the improved condi-

tions shown. When the adjusting screw is in control, the engine will slow down much more quickly than without it, and the engine would be stalled by a lighter load; it would also take more time to do a given amount of work.

7 As engineers prefer to have engines with some power in reserve to take care of the abnormal load, I believe they would hesitate before using any method of control that eliminates the reserve power of the motor to which it is applied.

8 From a study of the Indiana Steel Company's plant at Gary, Ind., it is evident that conservation of energy as applied to steel plants has received considerable study. The rolls are driven by motors, current being supplied by gas-engine generators.

James Tribe. In Par. 5, Mr. Caine refers to a certain engine capable of developing 25,000 h.p. while the average load does not exceed one-seventh of its maximum capacity. I do not know what engine he refers to, but a blooming mill engine of unusually large dimensions and answering somewhat to the description given, was built by the Allis-Chalmers Company and installed less than two years ago at the Carnegie Steel Company's South Sharon plant. This was a reversing engine for rolling 28 in. by 28 in. ingots on a two-high mill. The maximum power, or rather, the maximum possibility, of this engine, was likewise 25,000 h.p., which was also far in excess of its average load, but it is doubtful if there is in existence a more efficient reversing blooming-mill steam engine equipment.

2 In Par. 6, Mr. Caine asserts that in a three-high mill driven continuously in one direction, the energy stored in the flywheel would make it possible to do the same work with considerably less than one-half the power. There should therefore be some explanation to justify the installation of so large an engine, at so recent a date, and having so large a percentage of surplus capacity. There are two reasons for this: first, because of the stalling action at the moment the rolls bite the ingot; secondly, because of the probable increase of speed as the ingot is released.

3 The reversing engine, for well-known reasons, has no flywheel, consequently the momentum of the rotating parts is comparatively nothing. Therefore the stalling action at the instant of biting the ingot, due to the tremendous impact, which is followed immediately by an abnormally high tangential resistance at the rolls surface, creates a demand for an exceedingly powerful engine. It is just at this moment that surplus power, or reserve energy, is of the most

vital necessity in order to save time and heat which would otherwise be wasted while waiting for the engine to recover itself. At this critical moment the term "horsepower" does not explain the measure of effort necessary for overcoming this resistance; for as a less powerful engine would be almost, if not quite, brought to rest, two of the power elements, namely, time and space, are for the time being practically eliminated, and the engine reduced to a simple "force" acting on the crank pin. Hence, it becomes a question of a turning moment sufficient here to overcome the resistance, and of regaining normal speed in the shortest possible time: for loss of time means not only delay (which is very serious), but loss of heat, and loss of heat means additional power necessary.

4 In the second place, the engine must be so constructed as to be capable of permitting 25 per cent increase of speed above normal with perfect safety, for the reason that at the instant the ingot leaves the rolls, the slightest delay on the part of the operator in shutting off steam, all resistance except friction having been suddenly removed, results in an increase of speed and the safe limit is quickly reached. These two extreme conditions, full steam and abnormal speed, never occur at the same instant, in actual operation, but the engine must be capable of meeting them, and therefore such an engine may be said to be capable of several times its normal capacity.

5 So far as the gripping and the releasing of the ingot are concerned the effect is the same whether a reversing or a continuously running engine is employed; for the energy of a flywheel may to some extent prevent the stalling action, just as this is accomplished by the surplus capacity of the larger engine. But flywheel energy cannot be spent without a proportionate reduction in speed, and with loss of velocity more time must be taken to regain it than would be the case where the force of the steam is applied entirely in the mill. Part of the steam energy would be spent in restoring the wheel energy and consequently, more time would be consumed in the pass than is the case in a sufficiently powerful engine without a flywheel. This loss of time and heat partly offsets the apparent gain in economy of the smaller engine. But the more serious loss would be experienced in a three-high mill, in both time and heat, as well as the additional power required for raising and lowering the ingot to the two different levels for each succeeding pass. Considering the shortness of the passes in blooming-mill work, this delay would be a very serious loss.

6 It therefore seems to me that but little, if any, substantial advantage can be gained in heavy blooming-mill work by the three-

high mill so long as it is steam-driven. It also seems to me that the only hope of any improvement in economy over present practice will be in the use of the present two-high reversing mill, but driven electrically. In such an equipment, we would have the necessary power to avoid delay on gripping the ingot, the means for instantly throwing off the power at the release of the ingot, and also the continuously running steam engine with a sufficiently heavy flywheel at the generator.

E. W. Yearsley.[1] The value of the flywheel as a means to obtain constant load with intermittent work is well illustrated by Mr. Caine's experiments. This arrangement has been considerably developed in conjunction with electrically driven rolling mills. Where considerable speed variation is allowable, and there is a suitable ratio of pause to operation time, the flywheel may be applied to many drives with economy.

2 Economical considerations are at present of great importance in the steel industry. Engines used for driving rolling mills are usually excessive steam consumers. There is no doubt that their performance in this respect can be greatly improved, especially for continuously running mills. In my opinion the electric motor will be found more reliable and satisfactory for this work, and it will be desirable to confine the refinements necessary for great economy of prime movers to an electric generating station.

3 Mr. Caine's method of regulating the governor is somewhat analogous to that used for controlling the rate of application and the limit of electric current to a main roll motor, in order to obtain the similar results of more uniform load, less rapid speed variation, and protection of the driver. The tests show conclusively the improvement in steam consumption and performance resulting.

4 As the paper points out, the problem is considerably complicated by variation in the number of pieces passing simultaneously, also by variation of the interval between passes and its relation to the time of the pass, and in the temperature and composition of the material. A speed variation of from 12 to 20 per cent transferring from 23 to 36 per cent of the kinetic energy of the flywheel, has been found desirable. With a given torque, time of load, and interval, this speed change fixes the weight of wheel required. Data of power performance of rolling-mill drives are rapidly accumulating. This paper is an interesting addition to such information.

[1]Electrical Engineer, Midvale Steel Company, Philadelphia, Pa.

The Author. Mr. Ord seems to have the impression that there was a great difference in the work done in the two examples given. As a matter of fact, the area of the piece was the same in each case, on entering the first pass, and therefore, the total work for the four passes would be as their relative weights, 2680 lb. for Case A and 2550 for Case B; B having a slight advantage in weight, and A an advantage of 5 lb. in steam pressure, so that the work was practically the same in each case.

2 The valve setting was not altered between tests. The difference in the behavior of the engine was due to the adjusting screw alone; and now, three years after these tests were made, this screw is still in service. This method of engine control does not eliminate the reserve power; it does cut it down to a point where judgment says there is still sufficient reserve to answer all requirements.

3 Mr. Tribe asks the reason for building reversing engines with such a large surplus of power. Such engines are usually driving blooming mills, where it is no uncommon practice to roll about one-half of the total number of passes, from bloom to finished product, in one stand of rolls, the remainder being taken care of from three, four or more stands of rolls, so that the blooming mill must handle these passes in very rapid succession in order to get the tonnage. The engineer handles the throttle and reverse levers, and the roller, the screw-down and the table rolls. The screw-down adjusts the distance between the rolls; consequently it fixes the amount of reduction on the bloom and the load on the engine is proportional to the reduction.

4 The screw-down has no fixed limits for each pass, therefore it will be set in a very short period, according to the judgment, or lack of judgment, of the roller. The writer has timed these operations with a stop watch and found that quite often the adjustment was made in less than two seconds; that is, the time from the end of one pass to the beginning of the next. It is quite likely that the screw-down does not get located where the operator intended; if the reduction is less, the roller will make some other passes heavier because he does not wish to add two additional passes. From the calculated results, from continuous indication cards on an engine of this type, on a single bloom one pass was noted where no reduction was made, while another pass required nearly three times the average power. From this sort of operating conditions, coupled with the desire to get an engine that will not stall under any circumstances, it becomes very evident why there is a great surplus of power. This also calls atten-

tion to one of the features in favor of the three-high mills, namely, that the roll designer can distribute the work approximately equally on every pass, with the proper data at hand.

5 The fact that the reversing engine is man-governed is brought out. This practically places the speed limit at the rate at which it would run with a wide open throttle and nothing in the mill; which would far exceed 25 per cent of the normal. Speed curve A shows that our engines run at about 16 per cent above normal, and with curve B at but 10 per cent above.

6 Mr. Yearsley suggests that the principle involved might be applied to other than mill engines. The writer can cite an instance where this was done. Our company has two-crank flywheel hydraulic pumps which are started and stopped by an accumulator. When the accumulator would drop, the governing throttle valves would open wide and the pumps would run up to the speed determined by the fly-ball governors (50 r.p.m.), and when the accumulator reached the top limit it would shut off the steam, stopping the pumps very abruptly. This continual starting and stopping caused considerable trouble in keeping up the various adjustments, and pins ran hot at times. Upon my suggestion the engineer in charge adjusted the governing throttle valves so that they could be only partially opened, and as a result the maximum speed is just a little above the average, the pumps running almost continually at about 20 r.p.m., the trouble with hot pins is no longer experienced, the rod adjustments last several times as long, and it is my belief that the water valves must give less trouble.

EFFICIENCY TESTS OF STEAM NOZZLES

By Prof. F. H. Sibley and T. S. Kemble, Published in The Journal for Mid-November

ABSTRACT OF PAPER

The object of the tests was to determine the efficiency of various shaped nozzles with steam flowing from a given initial pressure to a known vacuum; also to determine the effect on the efficiency of changing the angle of divergence.

Two methods were tried out for finding this efficiency: (*a*) by first finding the pressure in the nozzle by means of a search tube placed axially in the nozzle; (*b*) by finding the reaction of the nozzle. This was done by suspending the nozzle in an air-tight box at the end of a flexible steel tube. The deflection of the tube caused by the reaction of the nozzle was measured by a calibrated spring. Friction was eliminated. Preliminary work was done to calibrate the springs, to determine the volume of flow of the various nozzles and to determine the pressure in the nozzle and the surrounding medium.

The results of the tests indicate: (*a*) that the reaction is affected by a difference in pressure between the muzzle of the nozzle and the medium surrounding the nozzle; (*b*) that the efficiencies of the various nozzles were determined within a probable error of 2 per cent: (*c*) that the efficiency is affected more by the smoothness of finish on the inside of the nozzle than by the exact contour of the nozzle.

DISCUSSION.

Prof. J. A. Moyer. The methods used in these tests are obviously much more accurate than the impact plate devices used by Lewicki in his experiments with De Laval nozzles and by others who have conducted similar investigations more recently.

2 The high efficiencies obtained may be surprising to some who have not followed the latest developments in the designing of steam nozzles. Results of this investigation confirm in general the results given by Steinmetz[1] and by the writer showing that the efficiency of a well-designed nozzle for relatively large, as well as for small, limits of pressure will be above 97 per cent.

3 However, in one respect the investigation is not as complete as it was hoped it would be. There are not enough data to determine the effect on the efficiency of varying the length of a nozzle: that is,

[1] The Journal, Am. Soc. M. E., May 1908, p. 628.

nozzles of different lengths, but with the same taper or angle of divergence, should be compared. However, the statement is made in the last paragraph of the paper that there is no appreciable difference in the efficiencies of nozzles 10, 11 and 12, which, however, do not have the same taper, but have the same *areas* at the throat and at the mouth. It is probable that all of these nozzles were longer than they should be to obtain the highest efficiencies. More data are needed about the best length of the nozzle for a given expansion. Lewicki's experiments cover the two extremes: nozzles which are obviously too short, and those which resemble in proportions the ones used in this investigation.

4 The error due to moisture in the steam could not readily be determined, and while it is probably not large, yet this uncertainty might have been avoided by using superheated steam. The reaction in a nozzle due to the flow of superheated steam is apparently constant for a varying amount of superheat. This can be shown by the usual thermodynamic equations for flow and velocity—which determine the impulse force of a jet— and by the experiments of Lewicki[1] on the flow of superheated steam through De Laval nozzles. It should be observed however, that when these tests were started, Knoblauch and Jakob had not yet published the values which we are now using for the specific heat of superheated steam, and for this reason alone it was desirable to avoid the use of superheated steam.

5 It has not been mentioned by the authors of this paper that their method can be used to calculate the *apparent* efficiency of any nozzle for any initial and final pressures. By measuring the areas of a nozzle at the throat and at the mouth or "muzzle," the expansion ratio in a nozzle is determined, and by means of empirical equations, due to Zeuner and others,[2] the ratio of the corresponding initial and final pressures giving the highest efficiency, can be obtained. This ratio of pressures would correspond to the condition in these tests where the terminal and box pressures are the same.

6 If the ratio of the initial to the final pressure has been determined, either of these pressures can be readily calculated if the other is known. For example, if by measurement of the mouth and the throat areas, the expansion ratio of the nozzle is found to be, say, 3, then the ratio of the initial to the final pressure must be nearly 13.3 for the maximum efficiency of the jet discharged from it. For

[1] Mitteilungen über Forschungsarbeiten, Heft 12, Zalentafel 9 (*c*). Verein deutscher Ingenieure, 1904.

[2] J. A. Moyer, The Steam Turbine, p. 40–41.

this nozzle, therefore, with an initial pressure of 200 lb. absolute, the final pressure should be 15 lb. absolute. From the equations given in Par. 4 of the paper, the theoretical reaction can be readily calculated from the available energy corresponding to the pressure limits. The change in reaction due to final pressures different from those for which a nozzle is designed is, then, according to the method presented here, the product of the area of the mouth of the nozzle, times the difference between the correct final pressure for the nozzle—in this case 15 lb. absolute—and the pressure in the box, or in practice the pressure inside the casing of a stage of a turbine. Since reaction and velocity are directly proportional—*with constant flow*—the apparent velocity of the jet will be increased or decreased in the same proportion as the reaction is increased or decreased.

7 In actual practice, however, this does not occur. It has been observed that if a nozzle is used which does not expand the steam sufficiently, there is not nearly so much loss in the velocity of the jet as when the nozzle is too wide at the mouth and "over-expands" the steam. In other words, it has been found that a nozzle which is about 25 per cent too large in area at the mouth, will give to the jet only 90 per cent of the theoretical velocity, while one which is too small by the same percentage will give within 2 or 3 per cent of the maximum efficiency obtainable with the pressures best suited. All this involves something which is not taken into consideration in these reaction experiments; and for that reason, the results obtained by this method with varying back-pressures may possibly be misleading.

Prof. C. C. Thomas. I have for years been interested in this line of investigation, and am glad to see this contribution. In Par. 26, the corrections which the authors make to the observed reactions seem to me to be somewhat open to question. Aside from this fact, I cannot quite see the theory upon which the corrections are based; the fact that the pressures vary considerably in all but perfect nozzles, from the center to the walls, and that very considerable irregularities of flow are found in nozzles, makes me doubt the necessity for making these corrections to the observed reactions.

Strickland L. Kneass. The tests appear to cover ordinary straight-tapered nozzles, as follows: 1 in 6, 1 in 5.77, 1 in 5, 1 in 4 and 1 in 3. In several cases the net areas vary slightly from these ratios owing to the displacement of the cylindrical search tube. but

the ratio of the throat area to the outlet area is practically the same for all nozzles, so that the results relate chiefly to the effect of the length of the tubes and the friction upon the walls.

2 From Table 5 it would appear that nozzle No. 13, which has a taper of approximately 1 in 4, gives a much higher efficiency between 100 lb. and 145 lb. absolute, than nozzles Nos. 9, 11 and 14, with tapers ranging from 1 in 3½ to 1 in 6. As far as the knowledge of the writer extends, there is no logical reason for this result, and he would attribute the higher percentages to greater precision in the experiments rather than to any inherent efficiency in the 1-in-4 nozzle.

3 The correct contour of a nozzle for the discharge of elastic fluid is still a moot question. After an extended series of experiments between the years 1888 and 1891 with steam nozzles of various tapers, the writer offered the suggestion that the section should be in the form of a reversed curve, somewhat as shown in Fig. 1 here-

Fig. 1 Suggested Form of Nozzle

with. This curve was based on the theory that the acceleration should be constant during the passage of the steam through the nozzle, and that the areas at the several sections should be unit distances apart. These sections were calculated with due allowance for the change in the specific volume of the steam during expansion. The results obtained seemed to confirm this theory and were compared with the discharge from straight-tapered nozzles in a paper read before the Engineers' Club of Philadelphia in 1891. The writer's opinion was further corroborated by F. Hodgkinson before the Engineers' Society of Western Pennsylvania in 1900. In view, therefore, of published experiments upon nozzles of special contour for which advantageous results were claimed, it is surprising that the authors of this paper did not increase its value by widening the scope of their experiments, instead of confining their tests to the oldest and possibly less efficient form of tube.

4 Referring again to the experiments of the writer, his conclusions covered the general theorem that there was little difference

in the efficiency of the straight-tapered nozzle, so long as the terminal pressure of the steam within the tube was the same as that of the medium into which it flowed, and, further, that the terminal velocity would be the same under this given condition whether the taper were 1 in 6, 1 in 5, or 1 in 3. This opinion seems to be sustained by the authors, although the results are not satisfyingly definite, because different terminal pressures were used with each initial pressure and the table does not contain the terminal pressures within the nozzle, so that the comparison cannot be made with the pressure of the final medium.

5 It is desired that this point be emphasized, for a slight difference between these two pressures has an important effect upon the results. It is thought that a more exact method of determining the relative efficiency would have been to modify the length so that the terminal internal and external pressures would always be the same, for when an attempt is made to introduce minus or plus reaction for correction, doubt is thrown upon the result. This is especially obvious to any one who by careful observation of the flow of steam through and from nozzles of different proportions, has noted the unstable equilibrium of the jet when the terminal pressure of the medium exceeds that within the end of the nozzle. Some of the minor discrepancies may be charged to this item and the writer is somewhat skeptical as to the accuracy of the results obtained in practice when calculated under the theorem given in Par. 26.

6 It would have been interesting if the authors had recorded new data relative to the action of the steam within the nozzle and determined the terminal specific steam volume. The writer maintains that the specific gravity of steam at different sections of the nozzle does not correspond to that calculated by the thermo-dynamic equation, and therefore would be glad to have the authors state if the velocity of the steam, as given in Tables 3 and 5, is equal to the specific volume based upon the adiabatic equation, divided by the cross-sectional area.

7 A test of this kind should give the initial condition of the steam. The authors state that a thermometer was placed in a well at the rear of the nozzle, but there are no figures in the table giving the percentage of moisture. An objection to the construction of the apparatus can be offered in the liability of condensation of steam in the vertical flexible supply pipe. The steam flows downward under pressures varying from 100 lb. (328 deg. fahr.) to 145 lb. (356 deg. fahr.) and is surrounded by steam at a pressure

of 28 in. vacuum (100 deg. fahr.) so that a certain amount is sure to be condensed.

THE AUTHORS. It appears to be a generally accepted fact that under-expansion in the nozzle is preferable to over-expansion. Stodola's Theory of Steam Shock and his search-tube experiments point very decidedly in this direction Reaction experiments may even *appear* to indicate that under-expansion in the nozzle is in some cases preferable to using the theoretically correct ratio. This may also be true; but if the theory advanced in Par. 26 is correct, it is impossible to accept the results of any purely reaction experiments as giving a definite answer to this question; and where the pressure in the muzzle of the nozzle is not taken into account, all the results may be in error.

2 Of course, it is possible to calculate the muzzle pressure by theoretical and empirical formulae; but if we are to rely upon theoretical formulae there is no object in conducting tedious and expensive experiments. Moreover, empirical formulae on this subject are at least liable to be based in part upon reaction tests which have not taken into proper account the pressure in the muzzle of the nozzle. Also when the nozzle discharges into a pressure which is considerably greater than the theoretical muzzle pressure, violent fluctuations occur within the nozzle itself, so that the formulae do not apply and the results of reaction tests may become very misleading.

3 Par. 26 has been called in question from both the theoretical and the practical standpoint, so that a more extended consideration may not be out of order.

4 The first statement, "The reaction of any nozzle is equal to the summation of all the components, parallel to its axis, of the pressures within the nozzle and in the chamber from which it leads," can scarcely be questioned.

5 The net accelerating force F (Par. 4) which produces the velocity actually present in the muzzle of the nozzle may be divided into two parts. One part (call F_f) is a summation of components of the forces with which the internal walls react against the pressure of the steam. The second part is a force due to the pressure of the steam in the muzzle, and acts in opposition to the first.

6 Let F_m be this second part, P_m the muzzle pressure, and A the muzzle area. Then

$$F_m = P_m \ A$$

and

$$F = F_f - F_m = F_f - P_m A$$

Let R be the "true reaction of the nozzle," i. e., the force which is equal and opposite to F. Then

$$R = F = F_f - P_m A \tag{1}$$

7 The apparent reaction (called R_a) is the force with which the nozzle actually pulls or pushes in the direction opposite to the steam flow during the test. The apparent reaction of any nozzle is equal to the summation of the components parallel to its axis, of all the pressures, both internal and external, upon the walls of the nozzle and of the chamber from which it leads.

8 That part which is due to the internal wall pressure is equal to F_f. The external pressure acts, in the direction of flow of the jet, upon an area which is greater than that upon which it acts in the opposite direction, the difference being the area of the muzzle.[1]

9 Let P_e be the external pressure. Then

$$R_a = F_f - P_e A \tag{2}$$

Combining (1) and (2) we have

$$R = R_a = A\ (P_m - P_e) \tag{3}$$

10 The rest of Par. 26 accords with these equations.

11 It is evident from this that any acceleration or retardation of the jet beyond the muzzle (due to the pressure into which it is discharged or to any other cause) cannot affect the true reaction, and that so long as the conditions within the jet are stable so that the muzzle pressure can be properly determined, there is no danger of being misled except by a failure to make the corrections.

12 When the pressure into which the nozzle discharges is considerably greater than the theoretical muzzle pressure, such violent flucuations ensue as to make all corrections impracticable, and the reaction tests under these conditions become worse than useless because they are misleading. The criticism by Professor Thomas is well founded with regard to such cases; but does not apply to the tests reported in this paper for the reason that these were all made under conditions which did not disturb the stability of the jet within the nozzle.

13 The fact that the corrected reactions shown in Fig. 13 and Fig. 14 lie in a horizontal line, i. e., are equal, is a further evidence that the theory upon which they are based is correct, also of the fact that the jet within the nozzle remained in very stable equilibrium,

[1] Gages connected to various points within the box showed that the external pressure did not vary in different parts of the box by as much as 0.01 lb. per sq. in. It must be remembered that the nozzle and the chamber from which it leads are here suspended within the box into which the jet discharges.

and that the creeping in of the external pressure along the internal wall had no practical effect, while the box pressure varied within the limits shown.

14 To show further the form of error involved in the failure to use these corrections, apparent and true reactions have been taken from Fig. 13 and Fig. 14, and the accompanying table computed.

Nozzle	i. p.	Flow Lbs. per sec.	Box t. p.	Reac.	Vel.	B. t. u.[1]	B. t. u.[2] Table	Eff.
11	145	.1536	0.929	18.134*	3796	288.0	317.4	90.75
14	145	.1550	1.632	17.821*	3698	273.2	289.8	94.28
11	145	1536	1.632	17.01†	3561	253.5	289.9	87.43
14	145	.1550	0.929	18.52†	3843	295.1	317.4	92.96
11	100	.1069	0.638	12.45*	3744	280.1	311.5	89.91
14	100	.1081	1.116	12.295*	3659	267.6	284.7	93.99
11	100	.1069	1.116	11.69†	3517	247 2	284.7	86.81
14	100	.1081	0.638	12 77†	3799	288.4	311.5	92.59

*Apparent and true.
†Apparent.

Data obtained from nozzles No. 11 and No. 14, with the box pressure equal to that in the muzzle of the nozzle, are given in lines 1 and 2. These velocities and efficiencies are the same as those given in Table 5, and require no correction for terminal pressure.

15 For line 3 the apparent reaction is taken for nozzle No. 11 with a box pressure which would be correct for No. 14, and the apparent velocity and efficiency of No. 11 are calculated from that basis.

16 For line 4 the apparent reaction for nozzle No. 14, with a box pressure which would be correct for nozzle No. 11, is similarly used.

17 It was found in the experiments plotted in Fig. 9 and Fig. 10, that the pressure conditions within the nozzle remained stable and practically constant with such variations from the proper box pressure for each nozzle. Also, by applying the corrections called for in Par. 26 it is found that these values reduce to the same values as those obtained in lines 1 and 2, showing that the velocity and efficiencies of the jets as they reached the muzzles were not affected by the changes in box pressure.

18 The acceptance of the uncorrected values would therefore imply an assumption that in nozzle No. 14, with an initial pressure of 145 lb. and a terminal pressure of 0.929 lb., the jet attained a velocity of 3698 ft. per sec. in the nozzle, and that after leaving the nozzle its velocity jumped to 3843 ft. per sec., and that in nozzle No. 11, with

an initial pressure of 145 lb. and a terminal pressure of 1.682 lb., the velocity of the jet after leaving the nozzle dropped from 3796 ft. to 3561 ft. per sec.

19 The efficiencies calculated from the apparent reactions, if accepted in this form, would show that No. 14 is better than No. 11, not only for its own proper terminal pressures, but for the terminal pressures found in the muzzle of No. 11 as well. It may be that such is the case; but there is considerable probability of arriving at erroneous conclusions if it is assumed arbitrarily, without having first been proved by very careful experiments which are not in any manner dependent upon the assumption for their accuracy. There certainly is no basis for making such an assumption from these data as it has no bearing whatever upon the subject.

20 Previous to the time when this series of tests was begun, there had been considerable investigation of nozzles with cone angles up to 12 deg.; but the action of steam in nozzles of greater cone angle had not received the same degree of attention. It was therefore decided to use nozzles with divergence angles of from 9 to 20 deg., it being then thought that this upper limit might be beyond the value for highest efficiency.

21 Another set of nozzles tested contained one with a cone angle of 24 deg. 30 min., which seemed to show an equal efficiency with those of smaller angle. This set was made of babbitt metal, was not perfectly smooth and was somewhat worn with long-continued use, so that the results could not be thoroughly checked.

22 With the steam conditions given and the ratio of muzzle to throat area determined therefrom, the only point left for the designer is the general contour of the nozzle, including the shape of cross section, length and angle or angles of divergence. The two sets of nozzles shown in Fig. 6 and Fig. 7 were designed with this in mind, each set having a common ratio of areas; those of Fig. 7 differing among themselves only in length and consequent angle of divergence, or vice versa, and those of Fig. 6 differing only in elements of general contour, not including length.

23 Professor Moyer's statement that "nozzles of different lengths, but with the same taper or angle of divergence, should be compared," is not understood, unless he means to suggest that the whole field of different steam expansion ratios should have been investigated. This was not permitted because of limitations of time and other circumstances familiar to most investigators. Such an investigation would not serve to determine the proper length for a given steam expan-

sion ratio, because the different nozzles would not be suited to the same steam conditions; but it would give the efficiencies for one angle of divergence with all the pressure ratios to which the various nozzles were adapted.

24 Each set contained one search-tube nozzle for use in determining experimentally the terminal pressure in the muzzle, to be applied in reaction tests on the rest of the nozzles in that set. The efficiencies of these nozzles, No. 9 and No. 13, as calculated by the search-tube method, are shown in Table 5; but they are not worthy of consideration except as an example of the inaccuracies almost certain to be involved in this method. The high efficiency given for nozzle No. 13 is not due to greater precision in the experiments, as Mr. Knease suggests, but rather to the great error in the search-tube method of calculation, caused by a very small error in determining the muzzle pressure. In Table 6 it is pointed out that a "+ error" of only 0.1 lb. per sq. in. in determining the terminal pressure would cause a "– error" of from 5.4 to 14 per cent in the "search tube computed" efficiency of No. 9 and No 13.

25 These "search-tube computed" efficiencies are evidently responsible for Mr. Moyer's statement that efficiencies were here found as high as 97 per cent. Values obtained from reaction tests are lower, and it is upon these that the conclusions stated in Par. 49 are based.

26 No. 9 ("search-tube" nozzle) was made with a small angle of divergence, to be doubly sure that the steam should not leave the walls before reaching the muzzle.

27 Both the length and the ratio of areas in nozzle No. 10 were made to correspond as nearly as possible with those in nozzle No. 9 so that the terminal pressure found in the muzzle of No. 9 might be applied to reaction tests upon the former with the least possible error.

28 No. 11 and No. 12 were made shorter and with a greater cone angle but with the same sectional areas, in order to find out what difference, if any, this would make in efficiency.

29 No. 18 was finished rough for comparison with No. 11, upon which the greater number of tests had been made.

30 No 14 was used to determine the efficiency with a smaller expansion ratio.

31 No. 13 ("search-tube" nozzle) was made to correspond as nearly as possible with No. 14, so that the terminal pressure as determined in the former might be applied in reaction tests with the latter.

32 No. 15 and No. 16 were used to determine the effect of these very considerable variations in contour.

33 Other forms, such as shorter nozzles or those designed for uniform acceleration and upon other theories, may and probably do give just as good efficiency as those herein described. It seems doubtful, however, in view of the uniform results obtained with nozzles of such different contour as those covered by these experiments, whether it would be advantageous to use any form especially difficult to manufacture, unless it be for the purpose of controlling the shape of the jet as it strikes the moving blades of the turbine. This is very important, as it has a great effect upon the efficiency of action in the blades.

34 It is to be regretted, as stated in Par. 19, that we were unable to procure a calorimeter of sufficient accuracy for our purpose, but such great care was taken to maintain uniform conditions in the boiler room, and these conditions gave such repeated indications of the dryness of the steam at the nozzle entrance, that the probable error introduced is not serious.

35 As stated in Par. 14, the steam left the boiler under a pressure not varying more than 2 lb. from 155 lb. gage, and with about 50 deg. fahr., superheat. Steam was throttled to the required initial pressure just before entering the flexible pipe, with the result that the thermometer inserted at the nozzle entrance showed about 4 deg. superheat with 700-lb. flow per hr. and sometimes a trace of superheat with 500 lb. per hr. It is probably fair to assume from this that the steam was dry when used with 145-lb. pressure at the entrance to the nozzle, and that (in view of the greater throttling which tends to offset the increased unit radiation from the pipes) there was always less than 2 per cent of moisture present even with pressures as low as 100 lb. abs.

36 It may be stated in conclusion that a proper method of determining the net effect of under and over-expansion in the nozzle would be as follows:

First: Make a set of nozzles of the same cone angle and finish with throats identical, and with muzzles of different areas.

Second: Determine accurately the proper terminal pressure and the true efficiency of each nozzle, by the method herein described, using a reaction apparatus in which static and moving friction has been eliminated.

Third: Find the push upon a set of turbine blades, using each nozzle discharging into its own proper terminal pressure and into the pressures which are proper for each of the other nozzles of the set.

Fourth: A comparison of the push exerted under these conditions, bearing in mind the "true efficiency" of each jet within the nozzles, will show the net effect of under and over-expansion.

GAS POWER SECTION

THE WORK AND POSSIBILITIES OF THE GAS POWER SECTION[1]

By Fred R. Low, Assoc. Mem. Am. Soc. M. E.
Chairman for 1909

The work of the Section for the second year of its organized existence has been largely formative. The art, to develop and to chronicle the development of which is our avowed purpose, is so recent even in its beginnings, so new in weighty accomplishment, that it is possible for an organization with our facilities to gather and put upon permanent record the main facts of its history and the precedents and data evolved in its development. Our endeavor should be to do this in such a way that another generation will have no regret based upon the failure of ours to make a full and intelligent use of its opportunities.

The Standardization Committee has presented a preliminary report dealing with the significance of various terms used in the art. While nothing that we can do or say will endow any of these terms or quantities with an arbitrary measure or value, your treatment and disposition of the report will go far toward determining the future usage upon which legal and other interpretations will be based.

The Committee on Literature is organizing so as to provide for the systematic reading of current gas power literature, and the filing of index and reference cards with the librarian so that future searchers may find available information grouped for ready reference, and the information itself either in the files or elsewhere in the library. This is not retroactive, however, and some steps should be taken, while present but perishable information is available, to put upon record the history of the art, to make up its complete bibliography, a roster of its personnel and a chronological statement of its achievements; to

[1]Address of the retiring Chairman at the annual meeting.

write the subject of gas power down to date as Professor Dalby has written that of heat transmission.

The Installation and Plant Operations Committees have been occupied in perfecting systems, and the forms submitted for your consideration are parts of such systems, which are thought to coördinate with and to supplement each other and to fulfil all the purposes of the Section. The work of collecting information along these lines will be vigorously prosecuted during the coming year, and any suggestions which will improve the efficiency or practicability of the system will be of especial value at the outset of the work. In addition to these records of regular operation some effort should be made to obtain information as to operating difficulties overcome, and truths as to the behavior of a gas power plant in the hands of the user.

A number of laboratories are available for research work, and the Section is asked to suggest lines of experimentation. A large number of suggestions boil down to 42 determinations which it is desirable to make upon fuels; 8 questions regarding test methods, the determination of which is a matter of debate rather than of experimentation; 20 questions relating to producer practice; 5 to the effects of various factors on engine capacity and efficiency; 11 as to the effect of various elements of design; 6 upon ignition; 4 upon regulation; 3 upon carbureters; 6 upon the heat of the exhaust; 11 upon jacket water; 7 upon operative questions; 16 upon meters and analysis apparatus; 5 on the indicator; and 1 upon fire risk. Not all of these require physical experimentation for their determination, but the Section is fortunate in having received offers of coöperation from several of the foremost interested professional observers and investigators with well-equipped laboratories and skilled assistants at their command, and their thought and work will be invaluable in settling aright these perplexing questions pertaining to a new industry.

The results of the Meetings Committee's work are before you in the papers which have been presented at this and the other meetings of the year

The membership of the Society has increased during the year from 247 to 378, a gain of over 50 per cent.

The development of the past year has been steady, along lines already laid down at its commencement, rather than productive of new lines of thought or endeavor. I do not know that the record of the past has been surpassed either in magnitude of unit produced or in efficiency of performance. There has been some difficulty in

the production of large cylinders which would maintain their integrity under the extreme conditions of pressure and temperature which obtain when the entire process of conversion from the potential energy of the fuel to the energy of a revolving loaded shaft is conducted within the cylinder itself; and a metal which can be cast, and which has the strength to withstand the pressure in thicknesses which will allow the walls to be effectually jacketed, is a desideratum. Cast steel has gone far toward solving the problem. An alternative is a modification of design which shall permit the use of wrought metals.

Mr. E. T. Adams said early in the year that we were nearer a 10,000-h.p. unit, looking forward, than to a 5000-h.p. unit, looking backward. He has designed a station of 100,000-kw. capacity, which with 5000-kw. units will take no more space than a station of equal capacity with 14,000-kw. turbines, and we hope to have the particulars of the design for an early meeting.

The gas plant has been handicapped by the excessive first cost natural to a period of evolution and rapid development, but with standardization of design there will be a material decrease of cost. Present estimates would indicate a relation of first cost as between steam and gas power plants of about 100 to 130. The use of high piston speeds has done much to decrease the cost of the gas engine per unit of capacity, speeds of 1000 ft. per min. being not uncommon.

In Northern latitudes, where heating is an important factor, or in factories where large amounts of heat are used in manufacturing processes, the internal combustion engine is at a disadvantge because its efficiency is surpassed by that of the steam engine, when the latter is credited with its rejected heat available for such uses. The rejected heat of the gas engine, less than that of the steam engine by reason of its greater efficiency, is still some 75 per cent of that supplied to it. A large amount of this heat comes out in the jacket water at a temperature of about 140 to 180 deg.; the rest in the exhaust gases at a temperature of upwards of 1000 deg. A practicable method of applying this heat to useful purposes will greatly increase the field of the internal-combustion engine.

A number of engineers are at work upon the problem. One manufacturer passes such gases through conduits beneath the cement floor of his shop, maintaining the room at a comfortable temperature. Another inventor uses the exhaust gases to make steam from the already heated jacket water, supplementing them when necessary by burning gases from the producer beneath the

boiler. He labors under the disadvantage that the returns from the heating and process systems are not cool enough to go into the jacket and make the process a closed heat circuit.

The year has witnessed continued and new attempts at a gas turbine, with no results about which we can talk in detail. Mr. Hans Holzworth, one of whose steam turbines was exhibited at the St. Louis exposition, has exhibited a small gas turbine which ran so satisfactorily that he had no trouble in obtaining capital for the building of a 1000-h.p. unit, upon which he is now engaged at Berlin. Mr. W. A.Warman, one of our New York members, is obtaining some very interesting results in his efforts to construct a Hero turbine, Avery engine or Barker's mill, operated by gasolene.

The difficulty in the gas turbine is, of course, to find materials which can deal at the same time with pressures and temperatures both high. In view of the remarkable results obtained by the addition of low-pressure steam turbines to reciprocating engines, the conception of a gas turbine in series with a reciprocating gas engine naturally arises. The terminal pressure and temperature in a gas engine are high. There is considerable energy to be had by expanding the gas to temperatures attainable even under atmospheric pressures. At the same time, these gases are not so hot when they come from the engine that they cannot be readily worked in nozzles of easily procurable material. It would be interesting to see this adaptation worked out, at least on paper.

Notwithstanding the attractiveness of the two-stroke cycle, the smaller weight of engine required, etc., no progress has been made during the past year except upon engines of the smaller sizes, and we appear to be no nearer to the wider use of the two-cycle engine in large sizes than we were two years ago.

The movement toward the better use of by-product gases goes on. All the large iron and steel works use their blast-furnace gases in gas-driven blowing engines, pumps and electric generators, and coke manufacturers are putting in by-product ovens. It is said that German interests will erect a by-product plant near South Bethlehem which involves an investment of some $4,000,000 to furnish coke to the Bethlehem Steel Company, and which will have available some 24,000,000 cu. ft. of gas per day, of a thermal value of 400 B.t.u. At 10,000 B.t.u. per h.p.-hr. this amounts to 40,000 h.p. continuously.

Efforts continue toward a producer which will satisfactorily and continuously handle the more abundant and cheaper bituminous coals without expensive auxiliary cleaning apparatus and if reported

performances hold good, the year may be credited with notable progress in this direction.

Increasing interest is being taken in the use of substitutes for coal and oil. Numerous peat bogs are being worked and both peat and lignite are successfully used in producers. This is especially true of Western lignite. Occasional references are made to the possibilities of using town waste in the same way, but we have not learned of any notable progress in this direction during the year, and it is still a question whether the vast carbonaceous rejecta of our large cities can best be made to contribute to our fund of available energy by way of the producer or of the still.

The United States Geological Survey has just issued a bulletin, bringing the question of alcohol as fuel down to date. Burned in engines especially constructed for it, Messrs. Strong and Fernald, authors of the bulletin, say that a gallon of alcohol will develop as much power as a gallon of gasolene, notwithstanding it has but 71,900 heat units per gallon, as against 115,800 for the gasolene. The present price of denatured alcohol is 50 cents per gallon in five and ten-gallon lots, more than twice that of gasolene; but untrammeled by an internal revenue tax it would doubtless be a serious competitor of the latter fuel.

The usefulness of the gas engine in marine work was considered by Mr. Straub in his paper presented to the Section at the Washington meeting. Rumors persist to the effect that a sizable war vessel is being built in Great Britain, to be propelled by internal combustion-motors, and we understand that a contract has been awarded for a 1000-h.p. outfit for one of our own lake steamers. The successful application of gas engines to the propulsion of canal boats in Germany is well known.

REPORT OF GAS POWER RESEARCH COMMITTEE

A few months ago the Executive Committee of the Gas Power Section, recognizing the importance of a well-considered plan for the solution of the problems developed by the increasing use of gas power, appointed a Research Committee consisting of Prof. Robert H. Fernald, Prof. L. P. Breckenridge, Prof. Rolla C. Carpenter, Dr. Chas. E. Lucke, Prof. W. D. Ennis, Prof. W. T. Magruder, Prof. Harry N. Davis, Prof. Lionel S. Marks, Prof. David C. Gallup and Prof. W. H. Kavanaugh, with instructions to advise as to the proper lines of investigation to be conducted.

This committee, with the secretary of the Section as secretary, has prepared a list of the special problems in connection with the use of gas power, the solutions of which are urgently needed. It has been suggested that the well equipped engineering laboratories of colleges and technical institutions would be glad to coöperate in this work, and it is hoped that many of these problems will be taken up by laboratories and investigators and the results made public through The Journal of the Society.

A LIST OF PROBLEMS, THE SOLUTION OF WHICH IS DESIRED

A Fuels:

1 Compile from reliable sources comprehensive data concerning the coals of the U. S. which are worthy of consideration for use in gas producers .... L. P. B.

2 Use in the engine of producer gas direct from the generator with its full charge of tar .... R. H. F.

3 Use of bituminous coals and other tarry fuels in suction gas producers. R. H. F.

4 Use of briquetted lignite in producer. (Some work has been done at the Fuel-Testing Plant, Pittsburg.) .... W. H. K.

5 Sage brush, wood, in the producer .... R. H. F.

6 Use of peat in gas producers and methods of preparing it for use. R. H. F., W. H. K.

7 Use of briquetted peat in producer.......... W. H. K.

8 Investigation of the rate (thoroughness) of dissociation of CO_2 in the producer at various temperatures .... W. D. E.

9 Ultimate analysis of ash in producer gas plants. (Also melting point of ash (clinkering) .... R. H. F., W. D. E.

10 Investigation of the temperatures prevailing in fuel beds of gas producers in conjunction with chemical investigations, R. H. F., L. S. M.

11 Ratio of air to fuel for best efficiency and comparison with theory. W. T. M., W. D. E.

12 Investigation of the effect on economic performances of varying the ratio of combustion.

(*a*) In different types of producers with same fuel.

(*b*) In same producer with varying sizes of fuel.

(*c*) In same producer with varying mixture of fuel.

(*d*) In same producer with coal mixed with limestone when the ash content of the coal is high........................... L. P. B.

13 Effect of depth of fuel bed in gas producer work............ R. H. F.

14 Effect of sizing coal on producer efficiency............... R. H. F.

15 Determination of the effect of preheating the air in gas producers. R. H. F.

16 Determination of the effect of varying the amount of moisture in the suction producer .... R. H. F.

17 Quantity of steam required per pound of fuel in producer gas plants. R. H. F.

18 Best rate of burning fuel in various types of gas producers. . R. H. F.

19 Effect of variable loads in producer work.................. R. H. F.

20 Possible utilization and value of various kinds of crude oils in various types of internal-combustion engines .... R. H. F.

21 Relative values of alcohol and gasolenes as fuels for internal combustion engines .... R. H. F.

22 Latent heat of vaporization of gasolenes, kerosenes and distillates. W. T. M.

23 Apparatus for the gasification of tar in connection with producer plants .... W. H. K.

24 Study of the use of blast furnace and coke oven gas........ R. H. F.

25 Application of injection of fuel to two-stroke cycle type of engine. D. L. G.

26 Conditions under which sulphur in fuel oils burns under pressure into SO_3, with subsequent formation of H_2SO_4 if water is present, either accidentally or by design .... H. N. D.

27 Investigation of the existence and commercial availability of fuel oils with exceptionally low sulphur content .... H. N. D.

28 Collection and determination of physical data for the constituents of fuel, particularly the hydro-carbons................. L. S. M.

29 Development of an oil gas producer making a permanent gas. W. T. M.

30 What are the requirements to crack a solid or liquid hydrocarbon.

(*a*) with the formation of tar.

(*b*) with the formation of soot or lamp black.

(*c*) with the formation of nitrogen compounds.

(*d*) with the formation of other liquid and solid resultants.

(*e*) with the formation of only fixed gases............. W. T. M.

31 Necessary temperature for the formation of fixed gases from a solid or liquid hydrocarbon, without the deposition of solid matter. W. T. M.

32 Between what temperatures has oxygen a greater affinity for hydrogen than for either carbon or carbon monoxide........W. T. M.

33 Use of tar as a fuel in producers..........................W. T. M.

34 Use of waste Pintsch tar as a fuel in oil gas producers.....W. T. M.

35 Use of waste Pintsch tar as a fuel in gas engines..........W. T. M.

36 Use of oil coke as a fuel in a gas producer.................W. T. M.

37 What are the conditions and chemical composition of the fuel which would cause to be preferred

(*a*) a down draft producer (suction).

(*b*) an up draft producer (suction).

(*c*) a pressure producer ....W. T. M.

38 Effect of coal washing on producer efficiency and ease of handling a gas producer ....W. T. M.

39. Methods for the utilization of the waste liquors from the scrubber, gas-washer, etc..W. T. M.

40 Combustion of fuel and generation of gas in a producer without the use of water ....W. T. M.

41 Methods of determining the amount of moisture supplied to the furnace of a producer ....W. T. M.

42 Methods of determining the percentage of ashes from a producer having a wet ash pit ....W. T. M.

B Tests:

1 Formulation of a proposed standard method of reporting tests of

(*a*) Gas producers.

(*b*) Gas engines.

(*c*) Combined units.

(In charge of Am. Soc. M. E. Committee.)...............L. P. B.

2 Formulation of a performance Record Sheet for the use of operating engineers, for both producer and gas engine. (Now being formulated by Plant Operations Committee, Am.Soc.M.E.)..........L. P. B.

3 Establishment of a standard of efficiency for producers similar to the Rankin cycle for engines, based on pure carbon with (*a*) air only, and (*b*) an assumed percentage of steam.................W. D. E.

4 Development of a method of testing gas producers without the use of an engine ....L. P. B.

5 Experimental determination of the temperature volume diagram in gas engines using different fuels ....W. T. M

6 Proper length of time for producer tests. (See Bulletin No. 393, U. S. Geol. Survey.) ....R. H. F.

7 Experimental determination of the factors in the heat balance of a gas producer and of a gas engine ....W. T. M.

8 Use of the temperature-entropy diagram in determining the probable means of improving the efficiency of the gas engine........W. T. M.

C Explosion Phenomena:

1 Methods of overcoming variation of quality of gas..........D. L. G.

2 Determination of the effect of eliminating the hydrogen from producer gas and its relation to maximum possible efficiency of the Otto cycle. R. H. F., W. D. E.
3 Determination of the effect upon the operation of the engine of varying the Hydrogen in the gas ....R. H. F.
4 Elimination of varying mixture with given gas and air supply due to improper mixing of the two..D. L. G.
5 Temperatures of gases in cylinder and of the cylinder walls..L. S. M.
6 Temperature of inflammation.
Velocity of propagation of explosion.
Temperature during explosion, etc........................L. S. M.
7 Completeness of combustion in an engine and the influence on it of speed, compression, etc..L. S. M.
8 Rate of giving up heat to the walls during the explosion stroke, by Dugald Clerk's method..L. S. M.
9 A study of Gas mixture to determine
(*a*) Pressures due to explosion of known volumes.
(*b*) Temperature of ignition.
(*c*) Effect of methods of ignition on (*A*) and (*B*).........L. P. B.
10 Effect of compression, within practical limits, on power and economy. R. H. F.
11 Effect of timing of valves on power and economy...........R. H. F.
12 Effect of speed on economy ....R. H. F.
13 Effect of speed on compression leakage ....R. H. F.
14 Effect of temperature and moisture content on explosion mixtures. R. H. F.
15 Effect of shape of compression space on combustion or economy. D. L. G.
16 Ratio of air to fuel common in automobiles.................W. D. E.
17 Investigation of the causes of pre-ignition and the temperatures causing the same with different fuels and compression ....L. S. M.
18 Effect of the location of the igniter on explosion phenomena.L. S. M.
19 Effect of dust and carbon deposits on pre-ignition and effect of dust on flame propagation ....G. A. O.
20 Effect of thoroughness of mixture on explosion phenomena...L. S. M.

D Power:

1 Effect of speed on power of an engine ....W. T. M.
2 Effect of atmospheric moisture on the horse power of an engine. W. T. M.
3 Variation of best economy with load.......................R. H. F.
4 Variation of volumetric efficiency with load................R. H. F.
5 The variation of friction with load in gas engines..........L. S. M.

E Design:

1 Effect of different ratios of wall surface to the volumes of the combustion chamber ....W. T. M.
2 Relative merit of valves with seat angles from 30 to 45 deg..R. H. F.
3 Effect of design of intake manifold on charge distribution in engine of more than one cylinder ....D. L. G.

4 Determination of the proper size of reservoir in order that varying loads on the engine may produce no fluctuation on the pressure of gas in the mains .... R. H F.
5 Effect of size of inlet valve on power in an engine of given size and piston speed .... W. T. M.
6 Relation between port area and cylinder volume in two-cycle engines and its influence on speed and power of the engine .... W. T. M.
7 A study of gas turbine possibilities .... L. S. M.
8 A study of the compound gas engine .... L. S. M.
9 A study of the multi-cylinder gas engine with low-pressure gas turbine for utilizing the exhaust .... L. S. M.
10 Measurement of temperature distribution and the consequent distortion in the cylinders of gas engines .... L. S. M.
11 A discussion of the state of the art in the cleaning and washing of fuel for the gas engine .... G. A. O.

F Ignition:

1 Relation of time of ignition to richness of mixture of fuel and air. W. T. M.
2 Relation of time of ignition to kind and chemical constituents of the fuel .... W. T. M.
3 Speed of ignition and maximum pressure obtained from different mixtures of air and fuels compressed to different pressures.... W. T. M.
4 Efficiency, as modified by method of electric ignition
(*a*) Wipe-spark.
(*b*) Jump spark.
(*c*) Hammer break with magneto.
(*d*) Lodge system.
(*e*) Seely system.. W. T. M.
5 Effect of system of ignition on rate of combustion.......... D. L. G.
6 Effect of multiple ignition on efficiency and power of an engine. W. T. M.

G Regulation:

1 Governing
(*a*) Compilation of data and descriptive matter.
(*b*) Comparison of methods in use.
(*c*) Test of different methods on the same or similar engines under the same load and same variation of load.......... R. H. F.
2 Control of speed in engines of the crude-oil type firing by ignition due to heat of compression.. D. L. G.
3 Throttling vs. automatic cut-off........................ W. T. M.
4 Relative efficiency with throttling regulation by varying quantity or quality of mixture .... W. T. M.

H Carburetors:

1 External vaporizers for kerosene and alcohol fuels utilizing heat of exhaust gases .... W. H. K.
2 Investigation to determine their effect on speed, power, mixture at different speeds, best mixture, ability to accelerate motor and car. R. H. F.

I Heat of Exhaust:

1 Methods of utilizing the heat in exhaust gases and jacket water for heating buildings ....W. T. M., W. H. K.
2 Possible utilization of exhaust heat in stationary practice . .R. H. F.
3 Best method of developing steam and power for operating gas producers, using waste heat if possible........................R. H. F.
4 Application of auxiliary exhaust in large engines ....D. L. G.
5 Determination of the heat of the exhaust gases of a gas engine, W.T.M.
6 Conditions for maximum and minimum heat carried away by the exhaust ....W. T. M.

J Jacket Water:

1 Effect of varying the temperature of the jacket water on the fuel consumption ....R. H. F.
2 Effect of fixed water circulation on economy for the purpose of determining value of thermostatic regulation of jacket supply. .D. L. G.
3 Investigation on the commercial practicability of Banki's scheme for lessening jacket losses by water injection......H. N. D., L. S. M.
4 Means of utilizing heat wasted in jacket water.............W. D. E.
5 Application of cooling towers to jacket water circulation. . .W. D. E.
6 A study of the relative efficiencies of air and water cooled engines. W. H. K.
7 Effect on economy and power of an engine by water cooling, (*a*) the piston, (*b*) the walls, (*c*) the heads, (*d*) the valves........W. T. M.
8 Heat-absorptive power of the piston, walls, heads and valves of a gas engine ....W. T. M.
9 Heat-absorptive power of different materials capable of being used in a gas engine cylinder ....W. T. M.
10 Relation of temperature of the jacket water to the power and efficiency of an engine ....W. T. M.
11 Conditions for maximum and minimum heat lost to jacket water. W. T. M.

K Operation:

1 Response of gas producers to sudden maximum demands, such conditions as might arise in naval practice ....R. H. F.
2 Time required to start producer plants from cold condition. .R. H. F.
3 Time required to start producer gas plants from a cold shutdown. R. H. F.
4 Lubrication: Discussion of the lubricants and the best methods of using them, the mechanisms for feeding and timing, and method of testing ....G. A. O.
5 Value of and best methods of mechanical stoking for gas producers. R. H. F.
6 Methods of determining standby losses in producers........L. S. M.
7 Use of unscrubbed and unpurified producer gas in a gas engine. W. T. M.

L Meters and Gas Analysis Apparatus:

1 Development of automatic gas samplers....................L. P. B.
2 Studies in gas calorimetry ....L. P. B.

3 Development of a convenient and practical continuous calorimeter. R. H. F.

4 An accurate method of measuring air and gas in large quantities when under variable but small pressure differences............R. H. F.

5 Development of a simple chronograph....................L. P. B.

6 Development of recording dynamometer ....L. P. B.

7 Development of methods of calibration of standard orifices suitable for measuring the flow of gases under small differences of pressure. L. P. B.

8 A heat gage which will indicate or record the calorific value of the gas which is being generated ....W. T. M.

9 A meter which will take into account the varying pressure and temperature of the gas passing through it..................W. T. M.

10 Development of a satisfactory method for determining the volume of gas generated by a suction producer....................W. H. K.

11 Accuracy of determining the volume of gas produced per pound of coal in a producer from the composition of gas, the ultimate analysis of the coal, and, for bituminous coal, the weight of the tar. L. S. M.

12 A gas analysis apparatus (including ash, soot, tar and gases) for use with producer gas before and after cooling and also before and after scrubbing ....W. T. M.

13 Development of a continuous gas analysis apparatus for producer gas and exhaust gases ....W. T. M.

14 Development of a gas analysis apparatus of the Orsat type and simplicity for producer room work ....W. T. M.

15 Apparatus for the analysis of the waste liquors from a gas producer. W. T. M.

16 Development of an accurate and sensitive pyrometer for gas engine work ....W. T. M.

M Indicator:

1 Design of an indicator cock or connection which will not cause premature ignition with producer gas ....W. T. M.

2 Improved methods of investigation of gas engines. Improvement of indicators. Methods of measuring air supply............L. S. M.

3 Development of continuous indicators ....L. P. B.

4 Development of quick acting thermo-couples..............L. P. B.

5 Development of an indicator for work at 3000 r.p.m........W. D. E.

N Insurance:

Relative fire risk of alcohol, gasolene and kerosene........R. H. F.

TESTING SUCTION GAS PRODUCERS

By C. M. Garland and A. P. Kratz, Published in The Journal for December

ABSTRACT OF PAPER

The paper describes a method of testing the suction gas producer which is independent of the engine. The engine is blanked off from the producer and a Schutte & Koerting steam ejector is inserted, which draws the gases from the producer and delivers them to a scrubber in which the steam used by the ejector is condensed. The gases then pass to a Westinghouse meter where the volume is determined.

A large part of the paper is devoted to the forms used in the computation and presentation of the results on gas-producer tests. Three forms are given, Nos. 1, 2 and 3. Form No. 1 is used only for the final presentation of the results of the tests; form No. 2 includes the results of all computations for convenience in computing; and form No. 3 contains the derivation and the discussion on the derivation of the formulæ used. The formulæ appearing in this form are arranged in the order of computation and the item numbers refer to the items of form No. 2.

The results of one test are included in the paper together with a graphical log illustrating the conditions during this test.

DISCUSSION

Prof. R. H. Fernald. In connection with the Government investigations, the feeling has prevailed that ever since the beginning of the work in 1904, gas producers could be tested on practically the same basis as steam boilers, i. e., without necessarily operating an engine in connection with the test. This would mean discharging the gas into the air in a manner similar to the discharge of steam in boiler test practice. This method of procedure has not been adopted at the Government testing station because so much prejudice has existed against the gas producer and gas engine. It has therefore been necessary that the gas generated at the testing station be utilized in an engine in order to avoid any discussion relating to the uncertainty of such operation. This has been particularly necessary owing to the large variety of fuels that have been handled and the variation

in the quality of gas produced. It is true, however, that from the producer standpoint alone the engine is not essential, and the method suggested by Mr. Garland is ingenious and reasonably convenient.

2 There are a few points in connection with this paper upon which further information is desirable. In Par. 5 it is stated that the weight of steam was measured by passing the jet through a calibrated orifice in a thin plate. Methods of determining the quantity of steam used by gas producers seem to be varied and the results obtained somewhat uncertain. I believe it would be interesting to know the details of the method employed by Mr. Garland. In the testing station at St. Louis the steam used by the pressure producer was determined by means of a calibrated orifice, but the fluctuations in pressure were such that the readings obtained were not regarded as absolutely reliable. During tests covering a period of approximately two years the steam used varied from 0.28 lb. per lb. of coal fired to 1.13 lb. of steam per lb. of coal fired. The average for twenty consecutive tests showed 0.69 lb. of steam per lb. of coal fired. It should be borne in mind that the fuels used for the different tests were quite different in composition and that the amount of steam required by the different fuels may have varied considerably; but in spite of this fact the feeling which prevailed about the plant was that the method of determining steam by means of calibrated orifices was not entirely satisfactory unless the pressure of the steam passing into the producer, and the percentage of moisture in the steam, could be kept constant during the test.

3 At the Norfolk station, however, the steam required by the producer was supplied by an auxiliary boiler, so that all water passing into this boiler could be positively measured. Although the coals used for the six tests reported below were practically the same in composition, yet the records show the steam consumption per pound of coal fired to be decidedly variable, as follows:

(1) 1.12 lb. per lb. of coal fired	(4) 0.82 lb. per lb. of coal fired
(2) 1.14 " " " " " "	(5) 0.77 " " " " " "
(3) 1.04 " " " " " "	(6) 0.69 " " " " " "

This wide variation shown for these six tests is due entirely to the methods of operation, and not to uncertainties in measurement, as might at first be inferred. There is need of systematic and careful investigations relating to this question of steam per pound of fuel. At the Pittsburg station the method of determining the amount of steam used in the vaporizer is by means of a water tank calibrated in pounds, thus insuring accurate measurement.

4 In Par. 6 is presented the general method of determining the amount of fuel used. One phrase attracts especial attention: "at the end of the test the fuel bed being brought to as near the starting condition as possible." In boiler practice where the quantity of fuel on the grate at any one time is relatively small, it is undoubtedly possible, within a reasonable percentage of error, to determine the condition of the fuel bed and to make this condition practically the same at the beginning and close of an eight or ten-hour test.

5 However, the situation is totally different in gas-producer practice in which the initial fuel supply and the amount of fuel on the grate at any given time is large compared with the amount required by the plant during a run of a few hours only. Even though the conditions at the close of a producer test be made to duplicate those at the beginning, there is still considerable difficulty in determining the exact fuel consumption, owing to the lack of accuracy in determining the true thickness of the fuel bed. In a producer of 250 h.p. rating it is not uncommon to make an error of from four to six inches in the true depth of the fuel bed. In a producer of this size, this will cause an error of about 800 lb. of coal, or about 400 lb. of coke, according to the condition of the fuel bed at the time. It is imperative, therefore, that the tests of producer plants be continued to such length that these errors in measurement will be but a small percentage of the total fuel consumed.

6 Mr. Garland states that it was endeavored to make the tests of such duration as to bring the probable error of filling down to about two or three per cent. It will be of interest to have explained in further detail the method of procedure used in determining the exact amount of fuel consumed. With a 250-h.p. plant in which the fuel consumption for a period of 8 hr. amounts to only 1800 lb. approximately, the error due to inaccurate measurement of the depth of bed and variations in fuel bed thickness may be as great as 1150 lb. The percentage of possible error in calculating fuel consumption for short periods is obviously great. With a period of 24 hr. and a fuel consumption of about 5400 lb., the percentage of possible error, although much less, is still over 20 per cent.

7 In the producer tested the effective fuel bed volume was approximately 4 cu. ft., which is equivalent roughly to 250 lb. of anthracite pea coal. It is probable that a large percentage of the gas value of this coal may be given off without materially decreasing the fuel volume, under certain conditions of fuel bed. In a run in which the fuel consumption for this producer amounts to only 800 lb. with an

initial bed of 250 lb., it is a question whether the percentage of error in fuel bed estimates may not amount to 10 or 12 per cent instead of 2 or 3 per cent.

8 In a recent paper on this subject published by the United States Geological Survey, the following conclusions were presented:

a Throughout a test the fuel bed should be maintained in uniform condition, with regard both to character of the fire and thickness of the bed.

b Failing in this, special care should be exercised to see that the fuel bed is in the same condition and of the same thickness at the close of the complete test or at the end of a test period, as at the beginning.

c A test should never be started when the producer has been standing idle for some time with banked fires, as the fuel bed will not be in the average condition under which it will be required to work during the test.

d If, as the appointed hour for closing the test approaches, the fuel bed is not in the proper condition, the time of ending the test should be postponed until the bed naturally assumes the proper thickness and character. No forcing of conditions should be allowed simply to bring the test to an end at a previously determined hour.

9 In Par. 12 it is suggested that the volume of gas may be computed from the analyses of the gas and coal and the statement is made that this "may be relied upon within 5 per cent, provided the sampling is accurate." This last clause "providing the sampling is accurate" seems to contain the essential point. Time does not permit a lengthy discussion of this important subject, but too much emphasis cannot be placed upon the fact that proper sampling is difficult to accomplish.

10 Reference to the packing of the ash in the fuel bed suggests another point which must be very carefully considered in making fuel bed measurements, viz., the swelling of any coals due to the application of heat. Frequently in our government tests, the measurements of the fuel bed have caused very misleading impressions due to the fact that the fuel had swollen materially during the operation of the plant.

11 In Form 1 a number of items appear under a heading "Quantity of Air." Although it is quite possible to determine small quantities of air with some degree of reliability, yet methods for making such measurements of large quantities appear to be entirely lacking.

Further details of the methods pursued in this test will, I believe, prove of interest.

12 In items 128 and 128*b*, are presented the producer efficiencies based on dry coal and combustible. It is not apparent why there should be a difference of 4 per cent in the efficiencies shown.

G. M. S. Tait. The usual method of testing a plant for such a short period would be to operate the producer for two or threedays beforehand so as to bring the fuel bed to an average working condition, that is, with an average amount of carbon in proportion to ash. Then a comparatively short run, provided great care was taken as to the fuel depth, would give fairly reliable figures. Otherwise, when drawing on a fresh fire and making a run of only twelve hours, it would be necessary to pull the entire fuel bed at the end of the run and analyze the contents for carbon and ash, in order that any sort of accuracy might be obtained.

2 In one of the author's tests, instead of 34 lb. of coal per sq. ft. of grate area, 8 to 10 lb. would be a normal figure, as 34 lb. of coal per sq. ft. is entirely impracticable for anything but a very short run on American fuels. In this test a large part of the coal originally in the producer was apparently burned to ash, and its consumption was completely left out of the test, causing very erroneous results.

3 Attention is called to the fact that the ash content in the ashpit is practically much less than the ash content of the fuel, as shown by analysis. The balance of the ash is undoubtedly in the fuel bed and its presence there entirely upsets the basis of calculation for this paper. It is safe to say that a two days' run would have given a reversal of the first day's figures.

H. H. Suplee. I would like to speak of the unreliability of an orifice as a means of measuring. Only this morning a member called my attention to the discharge of steam from a boiler in which the orifice and all conditions surrounding it were identical in several tests. The amount of steam generated was measured by carefully weighing the water, double-checking it in tanks, and yet there was a variation of ten to fifteen per cent in the results, the steam pressure and the temperature being kept as uniform as possible. This fact casts a doubt on the orifice as a means of determining flow.

L. B. Lent. The figures given show that the draft through the producer was practically 1½ in., and yet 38.8 lb. of dry coal was

burned per sq. ft. of grate area. Still, with this consumption the producer efficiency seems to be very good. My impression is that this is a remarkable rate of consumption in producers of large type; and I would like to know if this is the common practice in smaller sizes of producers.

H. F. Smith. Regarding the conditions of the fuel already discussed it seems to me that the author has presented all the necessary evidence to show that the conditions in the fuel bed were not the same at the end as at the beginning of the test.

2 In the graphical log in Fig. 3, it will be noticed that the temperature of the gas leaving the producer at the beginning of the run was 400 deg. fahr., and at the end of the run something over 1300 deg. fahr. The rates of gas production and fuel consumption were practically uniform. It is evident that there was some variation in conditions, otherwise this difference in temperature would not have occurred.

W. B. Chapman. Perhaps I can answer Mr. Lent's question in regard to the quantity of coal gasified in producers. Producers for furnace work are usually rated at 10 lb. per sq. ft. of internal diameter on Pennsylvania coal, but only 7 lb. per sq. ft. on Illinois coal. The best record I have seen for *hand-operated* bituminous coal producers was 16 lb. per sq. ft. Mechanically agitated producers gasify from 15 lb. to 30 lb. per sq. ft.

2 The question of the amount of anthracite coal that can be gasified is very interesting. Engineers from abroad say that two or three times as much can be gasified as is the custom in this country. Every gas producer manufacturer in this country having a foreign engineer in charge has designed his first producer very much too small. The more experienced manufacturers do not rate their producers at more than 10 lb. per sq. ft.

3 It is strange that we cannot get the results said to be obtained in foreign countries. The difference must be in the coal.

Prof. R. H. Fernald. In reference to the rate of burning per square foot of grate area, I desire to call attention to the high figures shown by Mr. Garland. These figures seem to be very unusual for this type of producer even under the test conditions described. The highest rate with which I am familiar in commercial operation is that found in the case of a large installation using lignite as fuel. This

plant shows a daily rate of 33 lb. per sq. ft. of fuel bed area per hour during 16 hours each day and 48 lb. during the remaining 8 hours. In this installation the producers are of the down-draft type, but even under these conditions this rate is, I believe, exceptional.

2 In reference to Mr. Chapman's remarks about the manufacturers abroad, I would say that apparently all of them stipulate the type of coal that shall be used in their producer. They specify that the coal must be of such and such a grade, non-caking and with only such and such a percentage of ash and tar. As nearly as I was able to ascertain, practically every manufacturer abroad has reached the conclusion that it is wise to designate definitely the coal to be used.

3 In one suction producer in Germany, operating on bituminous coal, I found that the successful manipulation of the plant was due to the fact that three kinds of coal, mixed in the proper proportions, were being used. In other words, this type of producer using bituminous coal as fuel was entirely feasible in the home plant of the manufacturer, but it would hardly prove a saleable article in this country, as it would be almost impossible to guarantee the three required grades of coal at all times. It would also be out of the question to secure operators at a reasonable compensation who would give the plant the required attention.

E. N. Trump. The rate of combustion in producers using anthracite coal depends very much upon the size of the coal. Seven tons per 24 hours, with a producer 7 ft. in diameter, is about the maximum for No. 1 buckwheat coal. This equals 15 lb. per sq. ft. of grate surface per hour.

2 Burning Western coals in producers, especially Hocking Valley coal, a high rate of combustion is obtained. I have operated producers continuously for a considerable period at the rate of 42 lb. per sq. ft. of grate surface. This is with a large percentage of steam in the air, also with mechanical ash extraction, the fuel bed being thus kept well agitated.

2 Venturi meters give very accurate results in the measurement of both gas and steam, much more accurate than the simple orifice.

The Authors. It will be well to emphasize the fact that the producer under discussion was designed and intended for intermittent service only; that is, it is not suitable for runs of greater than 12 to 18 hours duration. This is due to the small size of the producer, and

the absence of charging bell, water-sealed ashpit and mechanical means for agitating the fuel bed.

2 Owing to the small size of the producer and the absence of means for thoroughly cleaning the fuel bed from time to time, as above noted, the accumulation of ash toward the end of 12 or 15 hours of continuous operation is so great as to necessitate such thorough cleaning as seriously to lower the heating value of the gas.

3 From the foregoing it will be evident that our test corresponds to the conditions under which the producer is normally operated. Owing to the thorough cleaning of the fires before starting the test, and the removal of the ash from the grate, a large quantity of green fuel is brought into the path of the outgoing gases, resulting in their being cooled. At this time, the temperature of the fuel bed is also lower, as indicated by the analysis of the gases over the first two hours of the test. The heating value of the gas is not lowered, for two reasons: first, the descent of the green fuel into the path of the gases results in the distillation of the CH_4 and other heavy hydrocarbons; secondly, an increase in the percentage of hydrogen results from the lower temperature of the fuel bed.

4 At the close of the test the fuel bed was evidently at a higher temperature than at the start. This resulted in increasing the unaccounted-for loss in the heat balance, but its extent (estimated from the results of a number of tests) is about one per cent for the present test. This, it is believed, explains the condition pointed out by Mr. Smith.

5 Professor Fernald and Mr. Tait call attention to the probable inaccuracy in determining the weight of coal fired on the test. We have recognized this source of error, and in Form 2 have included such items as give proof of the accuracy of the work through the stoichiometric relations. As the full import of these items has evidently not been realized, we will amplify them.

6 First, to determine approximately the purely mechanical error in estimating the weight of coal fired during the present tests, the producer was filled four separate times, and the weight of coal required was noted in each case. The average of the four weights was taken as the mean or true weight of coal required to fill the producer. The results are given in Table 1, herewith. It will be seen from this table that the maximum variation from the mean is 8.75 lb., or 1.7 per cent. This in the test under consideration represents an error of probably 1.1 per cent.

7 Mr. Tait seems to think that the presence of the ash in the fuel bed "upsets the basis of calculation for this paper." The total weight of ash in the dry coal is 776.5 lb.; 13.17 per cent = 102 lb., of which 52 lb. was taken out in the ash and refuse, leaving 50 lb. remaining in the fuel bed. This would seem to indicate an error of 6.3 per cent, due to failure to remove this ash. Since the ash is soft and fine it would pack into the interstices between the coals so that its volume would by no means displace the same volume of coal. If it displaced one-half its volume of coal it would cause an error of slightly over 3 per cent. It is probable that its presence caused even less error than this. In order to bring out the different errors we will analyze the conditions existing on the test.

TABLE 1 WEIGHT OF GREEN COAL REQUIRED TO FILL THE PRODUCER

Trial Number	Weight Lbs.	Variation from Average Weight	Per Cent Variation
1	669.25	−8.75	1.70
2	676.25	−1.75	0.26
3	683.25	+5.25	0.77
4	683.25	+5.25	0.77
Total	2712.00		
Average	678.00		

8 It is probable that the composition of the producer gas on leaving the scrubber, and at any two points in the cross section of the main, is the same. In order to eliminate such an uncertainty, however, we have taken the gas for our samples simultaneously from different points in the cross section of the main and at a point beyond the scrubber, by means of the sampling tube illustrated in the paper. These samples were taken continuously over the period of the test, both for analysis and for the calorimeter. The heating value of the gas, as computed from analysis, is 138.1 B.t.u. After corrections were made for the error in the meter, the error due to the vapor pressure of water, and the error due to radiation and conduction into the calorimeter, the heating value of the gas as determined by the Junker calorimeter was 137.3. Since the heating value as determined from two separate samples of gas, by two independent methods, and by two independent observers, checks within 1 per cent, it must be admitted that the sampling, the analysis and the heating value of the gas are probably correct within less than 1 per cent.

9 The volume of gas generated by the producer was measured by

a Westinghouse meter, guaranteed by the company to be accurate within 2 per cent. However, as a further precaution, the meter was carefully recalibrated and was found to be accurate within this limit. A calibration curve was plotted from the calibration, so that the error in determining the gas volume must have been within 2 per cent, and was doubtless even closer than this.

10 As shown by a number of tests on the present fuel, the coal was fairly uniform. A sample representing about 15 per cent of the coal fired was mixed and quartered until about eight or ten quarts remained. This was then ground, and again mixed and quartered until sufficient to fill a quart jar remained. The heating value from this sample as determined by the calorimeter was 13,040 B.t.u. per lb. The mean of eight determinations on this same fuel showed a heating value of 12,900 B.t.u. The probable error in the analysis and in sampling the fuel, judging from the heating value, is doubtless not greater than 1 or 2 per cent.

11 We have noted the volume of gas computed from the analysis of the coal and the analysis of the gases in Form 2, Item 126. This volume is 56,200 cu. ft. of standard gas, while the volume as actually measured by the meter, corrected for the vapor pressure of water, is 57,500, showing a discrepancy of about 2.3 per cent. The volume determined from computation was obtained from the formula of Item 126, Form 3. It is based on the fact that the weight of carbon in the coal fed to the producer must equal the weight of carbon appearing in the producer gas, plus the carbon lost in the ash, plus the carbon lost in soot and tar, plus the carbon lost by the absorption of CO_2 and CO by the scrubber water. The carbon lost in the ash is readily obtained, the carbon lost in the soot and tar is not over 1 per cent, while the carbon lost through the absorption of the gases by the scrubber water is also very small.

12 It may be well to compute the carbon in the gas and compare this with the carbon fed to the producer in the coal. We will compute the latter first. The total carbon in the coal is 0.7984 x 776.5 = 620 lb. The total carbon in the ash is 0.388 x 85 = 33 lb. The carbon that should appear in the gas is therefore 587 lb. The total weight of gas from Item 131, Form 2, is 3912 lb.

Carbon in CO_2 of gas	=	$0.0716 \times 12/44 \times 3912$	= 76.4
" " CO " "	=	$0.2925 \times 12/28 \times 3912$	= 490.5
" " CH_4 " "	=	$0.0112 \times 3/4 \times 3912$	= 32.8
			599.7

Thus 599.7 lb. is the total weight of carbon appearing in the gas as measured by the meter. $599.7 - 587 = 12.7$ lb. of carbon unaccounted for $= \frac{12.7 \times 100}{599.7} = 2.1$ per cent. As already stated, there may be an error of 1 per cent in the meter by which the above volume of gas was determined, the error being either positive or negative. There may have been 1 per cent of carbon lost in the soot and tar, but not more than this; there may also have been an error in the analysis of the coal amounting to $1\frac{1}{2}$ per cent. We estimate the principal errors in the test as follows:

	%
Error in filling the producer	−2.1
Gas analysis or heating value of gas	±0.7
Volume by meter	±1.5
Coal analysis and sampling of coal	±1.5
Carbon lost in soot and tar	−1.0
Loss in sensible heat in the fuel bed due to the lower temperature at the start than at the close of the test	−1.0

The total error in the results of the test that would affect the cold-gas efficiency of the producer, if all the above errors are assumed as accumulative, equals .8. The probable error is 2.7.

13 There are three other errors that may affect the heat balance, namely, the error in measuring the temperature of the outgoing gases, the error in the determination of the specific heat of these gases, and the error in the amount of steam fed to the producer. The error in measuring the temperature of the gases may be 2 per cent; the error in determining the specific heat of the gases may be 6 per cent; the error in determining the steam fed to the producer may be 25 per cent. If these errors are accumulative, the first two represent a total error based on the heating value of the fuel of about 2 per cent, and the third of about 1 per cent. Therefore, if all errors are accumulative, the total error in the heat balance is about 6.8 per cent; as some of these errors will be positive and others negative, the probable error in the heat balance is about 3.5 per cent. As the heat balance shows an unaccounted-for loss of 4.4 per cent, about 1 per cent being radiation and conduction, the actual error in measuring the coal delivered to the producer on this test could not have exceeded 3 per cent. We have therefore been able to run tests of such duration as to reduce the probable error in filling the producer to 2 or 3 per cent. Furthermore we believe the results indicate that they are above the average in

accuracy for this kind of work, as we have seen very few tests on producers that would stand the above analysis.

14 As Professor Fernald and Mr. Suplee have pointed out, we have found the use of the thin plate orifice for the measurement of steam not altogether satisfactory. As the heat supplied in the steam on most of our tests is small, a large error is permissible in the measurement. Our aim has been to vary the pressure on the orifice so as to keep the hydrogen content of the gas practically constant. It might be well to state that the orifice was used only while we were obtaining a new vaporizer for the producer.

15 We have found no tendency in the anthracite coal to swell. We believe that this is a property of bituminous coal containing large quantities of moisture and of hydrocarbons.

16 As the quantity of air does not enter into the computation of the more important quantities, it was computed from the nitrogen in the producer gas. The formulae for this computation are given in Form 3.

17 The difference in the efficiency based on dry coal and the efficiency based on combustible, as noted by Professor Fernald, is due to the fact that we have used the word combustible as defined in Form 3, Item 54. This takes into account the grate efficiency. The result is that the efficiency based on combustible corresponds to the efficiency based on 100 per cent grate efficiency. It is used for the reason that it is often desirable to show relations between efficiency and other quantities that are independent of the grate efficiency.

18 The amount of coal burned per square foot of grate area is a very variable quantity and depends upon the size of the fuel, the kind of fuel, the nature of the ash, the amount of water supplied, the proportions of the producer, the operation and the length of run.

19 For intermittent work, such as the present producer is adapted for, and with coals containing an ash infusible at temperatures under 2300 deg. fahr., it is possible to operate at several times the capacity possible with coal containing a fusible ash which necessitates a low fuel bed temperature.

20 The rapidity and extent of the reaction of CO_2 on incandescent carbon depend upon the temperature and upon the catalytic action of the fuel. At a given temperature and an indefinite time of contact of gases with the incandescent carbon, a definite amount of CO_2 and CO will be formed. The lower the temperature the less the per cent of CO formed and the longer the time required for equilibrium, so that with low temperature in the fuel bed the time of contact of the

gases with the fuel must be greatly increased. The same is true for the reaction of water on incandescent carbon. Harries[1] passed water vapor over incandescent carbon at different temperatures and obtained the results given in Table 2. These results show the effect of temperature upon the water-gas reaction. Due to the low temperature, the CO_2 is high, the CO is low and the ratio of water decomposed to water supplied is small. The latter fact, in the case of the producer, results in lowering the efficiency, as the undecomposed water carries out a large quantity of heat.

21 The curves of Fig. 1, herewith, taken from Dr. Clements'[2] work on the rate of formation of CO in gas producers, illustrates the effect of the time of contact, expressed in terms of velocity in feet per second, upon the amount of CO formed in passing CO_2 over incandescent anthracite coal. At a temperature of 1100 deg. cent., and a time of contact corresponding to a velocity of 1 ft. per sec., 11 per cent of CO is formed. If the velocity is reduced to 0.1 ft. per sec., so that the time of contact is increased ten times, 70 per cent of CO is formed. If an indefinite time of contact is assumed, equilibrium is reached at

TABLE 2 EFFECT OF TEMPERATURE ON WATER-GAS REACTION

Temperature Deg. Cent.	H_2	CO	CO_2	H_2O
674	8.41	0.63	3.84	87.12
838	28.68	6.04	11.29	54.09
954	44.43	32.70	5.66	17.21
1125	50.73	48.34	0.6	0.303

this temperature with 90 per cent of CO formed. This illustrates why it is necessary to use a small rate of combustion per square foot of grate area, due to operating with coals requiring a low temperature for the prevention of clinker formation.

22 If in the example just cited the temperature had been 1300 deg. cent. in the fuel bed, 70 per cent of CO would have been formed at a velocity of 0.5 ft. per sec. The time of contact would have been reduced five times, so that the rate of combustion could have been increased almost five times without appreciably changing the composition of the gas or the depth of the fuel bed.

23 In the case of our tests with the Scranton pea coal, we have

[1] Habers, Thermo-dynamics of Technical Gas Reaction, p. 138.
[2] Bulletin No. 30, Engineering Experiment Station, University of Illinois.

been able to vary the coal per sq. ft. of grate area from about 10 lb. to 45 lb., without appreciably affecting the efficiency of the producer. At the higher rates of combustion, however, the producer requires much more attention. If it were not for the fusion of the ash, the weight of coal per square foot of grate area could be increased indefinitely by the use of a blast and a sufficiently deep fuel bed.

24 The term "coal per square foot of grate area," as used in producer practice, is not, we believe, a true basis of comparison for the operation of different producers, for the reason that the coal per

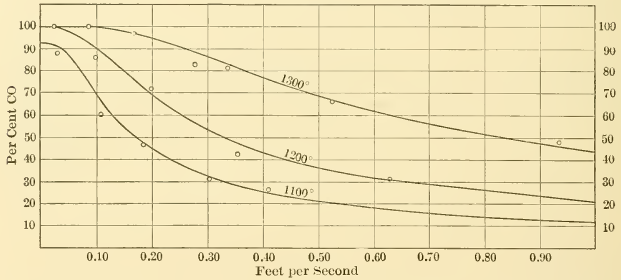

Fig. 1 Velocity of Gas in Feet per Second, Fuel Bed 1 ft. Deep

square foot of grate area depends to a certain extent upon the depth of the fuel bed. For this reason, largely, we have used a term, "rate of descent of coal through the fuel bed," or "coal per cubic foot of fuel bed per hour," which appears under Items 70 and 71 in Form I.

BITUMINOUS GAS PRODUCERS

By J. R. Bibbins, Published in The Journal for December 1909

ABSTRACT OF PAPER

This paper attempts to throw some light on the results of the development of a comparatively new type of apparatus, the double zone bituminous gas producer.

Much time and money have been spent by the various manufacturers in the development of a tar-free gas producer and in some respects the obstacles have seemed insuperable. Every advance is therefore of interest and importance, and it has seemed worth while to report a long series of tests conducted by the builder to determine the net results under commercial conditions, whether good or bad. These tests are characterized by their unusual duration and absence of outside conditions affecting the results.

These results in general will speak for themselves and it is necessary simply to emphasize the fact that continuous operation has been secured with tar-free gas of reasonable heat value and producer efficiency and an over-all plant economy of about one pound of fair bituminous coal per brake horsepower (proportionate economies for poorer grades). More important still, the fact has been developed that the efficiency and general effectiveness of operation of the producer on low grade fuel, lignites, etc., is practically as high as with the higher grades. This places within the reach of the producer the enormous fuel deposits of the West and South, which are practically invaluable for steam work.

DISCUSSION

G. M. S. Tait. The results reported in this paper are entirely in accord with what we have found, namely, that the gas of the lesser British thermal units is much more satisfactory for engine practice. In other words, the efficiency of a gas of 90 B.t.u. is proportionately double that of a gas containing 600 B.t.u. per cu. ft., the gases in question being respectively blast-furnace gas and gasolene vapor.

2 I would like an expression of opinion as to the reason for this great discrepancy in efficiency between the two gases, my own opinion being that the excessive normal losses are due to the sudden high temperature developed in the gas of high B.t.u., which is greater than can be handled by normal piston speeds.

3 The tar washer used in this test appears to be a succession of water seals and I would like to know what would be the total frictional effect of these seals under normal conditions and on full load.

4 In all producers properly designed the thermal efficiency appears to remain constant between 20 per cent and 100 per cent load. I can confirm Mr. Bibbins' experience as to the action of this particular class of fuel and its desirability for producer work.

Prof. R. H. Fernald. Mr. Bibbins places as his first essential requirement "continuous operation 365 days per year," and states that any departure from this condition means reserve equipment. He also states that the condition for producer operation must parallel steam boiler practice.

2 It is undoubtedly true that a producer which will operate continuously 365 days a year would prove a splendid commercial proposition, but it seems to me that in the requirements outlined the conditions imposed are much higher than those of any steam boiler plant and are beyond practical requirements. Every plant of any size must necessarily have one or more reserve units, as no plant can operate continuously 24 hours a day 365 days a year. If the producer described by Mr. Bibbins can approach this operating condition, it will certainly revolutionize our present day power-plant practice. It would seem advisable, in the light of the present development of gas producers, to impose conditions which are less severe.

3 Relating to the adaptability of a single producer to all classes of fuel, it is well to bear in mind that the government testing station has practically demonstrated the fact that almost any variety and grade of our recognized fuels can be handled with more or less success in a given producer installation without change of details of design. It is questionable, however, whether such practice lends itself to the efficient use of a wide range of fuels. It is probable that better results can be obtained by utilizing a producer type to cover a certain range or variety of fuels and another plant of somewhat modified design for another range.

4 Mr. Bibbins refers to the excessive labor required by most producers. At the present time the labor requirements are excessive for the majority of the plants utilizing bituminous coal. This labor, however, even under bad conditions of operation, such as those involved when the fuel is one that clinkers badly, probably does not exceed that of the average steam installation, although the labor is of a somewhat different character. During the regular operating

period of the plant this labor may amount to very little; but at the close of a week, two weeks, or any length of operating period, in the commercial plants now in operation, cleaning may be an exceedingly dirty, hot and tedious operation. With the steam boiler plant the labor is more uniformly distributed. In spite of the more erratic and more violent labor required at times by the producer installation, the total cost for cleaning, ash removal, etc., is probably within the limits of the average steam installation.

5 Experience with a large variety of fuels leads one to question whether the treatment accorded one fuel in order to prevent clinkering will produce the same results with a fuel possessing totally different characteristics. The impression from the tests carried on at the Geological Survey testing station is that fuels varying greatly in composition and in characteristics require widely different treatment. This impression has been obtained from tests on a large variety of fuels, but the number of tests on each of the different fuels was not sufficiently large to warrant positive conclusions regarding this point. European practice, however, seems to confirm this opinion, as practically every producer manufacturer finds it imperative to specify coals of certain characteristics for use in his type of producer and does not guarantee the plant on fuels outside of this class.

6 In the discussion of the results the point is brought out that with Texas lignite the rate of combustion in this producer can be so increased as to permit the same rating of the producer as when opering on a high-grade fuel. Note is made of the fact that a charging rate of 27.2 lb. per sq. ft. per hr. was obtained with this lignite. An installation in Texas, which I visited a year ago, consisted at that time of three producer units of 1100 h.p. rating each, or a total of 3300 h.p.

7 Owing to the character and high percentage of the ash, together with the excessive demands upon the plant each unit was cleaned every third day, or, what amounts to the same thing, one unit was cut out of operation during a part of each 24-hr. day. It required eight hours to cut out the gas from a given unit, to clean thoroughly, rekindle fires and cut in the new gas. During each 24-hr. day, then, the full plant capacity, rated at 3300 producer h.p. was in operation 16 hr., while only 2200 producer h.p. were in operation the remaining 8 hours. During the entire 24-hr. period, however, according to the operating records, the engines were developing 2800 h.p. The operating records also showed that the fuel consumption per square foot of fuel bed area per hour amounted to 33 lb. during the 16-hr. period and 48 lb. during the 8-hr. period.

8 The statement is made that the economy of less than 1 lb. per b.h.p.-hr. is probably below previous results in bituminous producers. It is assumed that this statement is not intended to cover the tests at the government testing station, which has reported a number of instances in which the consumption varied between 0.8 lb. and 1 lb. per b.h.p.-hr.

9 Mr. Bibbins states that perhaps the most important result is tar-free gas. It is undoubtedly true that tar-free gas is eagerly sought in all cases in which the gas is to be used in engines. In my own mind, however, it is somewhat questionable whether tar-free gas, as reported in this paper, means that the gas from any and all fuels used in this plant would necessarily be free from tar. Experience with a producer of somewhat different design shows tar-free gas with the majority of fuels, but in the case of certain fuels the results are quite the reverse. If the producer under discussion can produce tar-free gas from any and all varieties of fuel, it is certainly a development in the right direction.

10 In the closing paragraph of Mr. Bibbins' paper the impression is conveyed that the steam boiler units of 2000 and 3000 h.p. are found not infrequently, and that producer units are small in com-

TABLE SHOWING CAPACITIES OF PRODUCER-GAS POWER PLANTS

	No. of plants	Horsepower				Per Cent of Total	
		Total	Average	Minimum	Maximum	No.	H. P.
Anthracite Coal:							
Over 500 h.p.	8	7,550	950	600	1500		
500 h.p. or less	407	40,550	100	15	500		
Total	415	48,100	116	15	1500	88	43
Bituminous Coal:							
Over 500 h.p.	20	49,000	2,450	750	6000		
500 h.p. or less	17	5,150	300	35	500		
Total	37	54,150	1,460	35	6000	8	49
Lignite:							
Over 500 h.p.	3	7,275	2430	525	3750		
500 h. p. or less	19	1,725	90	25	250		
Total	22	9,000	410	25	3750	4	8
All Plants	474	111,250	235	15	6000	100	100

parison with the usual boiler unit. In my opinion the condition at the present time is quite the reverse of this. In European practice it is not uncommon to find producer units of 1250 and 2500 h.p., and in the United States units of considerable size are in commercial operation, as shown by the accompanying summary of the producer-gas power plants operating in June 1909. There are undoubtedly over 500 plants in operation, as the list includes 474.

11 It is true that many of these larger plants are made up of several units, but an inspection of the original data shows the following single units of 500 h.p. or more:

H.P.	No.	H.P.	No.
500	4	1000	10
625	6	1500	1
750	3	2000	7

One single unit of 3,000 h.p. and one of 4,500 h. p. are reported, but these figures have not been verified.

12 It is interesting to observe that about 88 per cent of the total number of installations in the country are operating on anthracite coal (a few using charcoal or coke) and that bituminous coal and lignite are used in the remaining 12 per cent. It is not strange, therefore, that the majority of plants are at present made up of relatively small units, although the number of large units is rapidly increasing as bituminous plants are becoming more common. In point of size the bituminous plants at present average 12½ times the size of the anthracite plants. Of the total horsepower approximately 57 per cent is derived from bituminous coal and lignite, and 43 per cent from anthracite coal, charcoal and coke.

13 Although in large central stations there are many operating advantages in relatively small units, yet it is believed that in the near future central station development will demand equipment of much larger capacity. A consideration of the fuel resources of the country indicates that in order to keep the price of power developed from fuel down to a consistent figure

- *a* Grades of fuel which warrant transportation, or which may be defined as "marketable," should be used with the greatest practical economy.
- *b* The very large percentage of coal of so-called low grade which today is left at or in the mine must be utilized.
- *c* Advantage must be taken of the large deposits of lignite and peat which are found in many sections of the country.

It is undoubtedly true that in general, under conditions which do

not require the use of steam for other than power purposes, the producer-gas power plant meets the requirements of *a*. At present the only method of advantageously handling the fuels mentioned in *b* and *c* is in the gas producer, and the utilization of these lower grades of fuel on an extensive scale demands concentration of large power units within close proximity to the fuel supply.

W. B. Chapman. In Par. 3, among the different requirements for successful operation, is mentioned the prevention of clinkers. I think the formation of clinkers can be avoided by the prevention of blow-holes or chimneys which allow the air to blow up through the fire bed, making hot spots. The average temperature across the hot zone in a producer is seldom high enough to produce clinkers. It is only in the neighborhood of the blow-holes that a sufficient temperature is attained to form clinkers. If the excessively high temperature necessary to the formation of clinkers existed throughout the producer, a clinker a foot or so thick would form immediately across its entire width. When ashes are melted they tend to run together, forming a clinker. The way to prevent this is to agitate the fuel bed continually, just enough so that the molten ash running down cannot take a permanent set in large masses, but is constantly kept in small pieces.

2 The successful producer should keep the fuel bed at an even temperature and uniform density throughout any horizontal plane. If there is a lesser density in any particular spot, the air blast immediately makes for this spot, causing an uneven temperature. To obtain this uniform density and temperature I believe that it is necessary to use some sort of mechanical agitation by hand methods, as no man or group of men can maintain a fuel bed of uniform density and temperature throughout any given horizontal plane long enough to get satisfactory results from soft coal.

3 Another point is that the successful producer should be made in a variety of sizes. The principles used in the producer described do not seem to admit of such variety. If this producer is of large diameter, the draft will go down the walls rather than in the middle, and the upper zone will not get hot enough in the middle to drive the tar out of the coal. If the tar is not removed by high heat in the upper zone, it is sure to get to the engine.

4 A successful producer should not require a delicately balanced draft, for the "balance" is often difficult to maintain. Uniform density in the two zones is imperative in double-zone or balanced-

draft operation, as otherwise the draft will vacillate from one zone to the other according to their varying density or resistance. The density is apt to change with the loads and with change of operators. The density will also change when the ashes are removed, as during this process a cavern is often formed which drops suddenly. In a producer of this type I have seen the vacuum vary from 2 in. to 18 in. in the lower or up-draft zone, and from 10 in. to 30 in. or more in the upper or down-draft zone.

5 In Par. 21, referring to the question of varying the air supply to the engine according to variations in the heat value of the gas, Mr. Bibbins says: "But this variable factor has received practically no attention and as a consequence producer operators are working entirely in the dark." To my mind the proper way of overcoming this difficulty would be to provide suitable mechanical means for maintaining uniform conditions in the organization of the fuel bed.

H. M. Latham. I think Mr. Bibbins has struck the keynote in regard to bituminous gas producers, when he says that the primary requisites are continuous operation and tar-free gas. There is no question in my mind that these are the most important considerations. Any producer which satisfactorily meets these requirements should have a large field of usefulness.

2 We have already seen from the figures presented by Professor Fernald, that the bituminous producer is at present the predominant type, and it seems probable that future development, especially in large units, will be along this line. In New England the high cost of anthracite coal suitable for use in producers of the strictly anthracite type, offers serious objections to its employment as a fuel.

3 As regards continuity of operation, while it goes without saying that a certain reserve power should be provided, yet it is frequently convenient and desirable in installations where power is required every day in the year, to be able to operate without calling upon the reserve, or in other words, to run absolutely without interruption.

H. H. Suplee. In regard to the question of continuous operation, I think Professor Fernald will remember that we have had a number of gas producers running continuously in this country and elsewhere, not for one year only, but for a number of years, but we did not call them gas producers; we called them blast furnaces. But I hardly think we care to run our producers continuously.

2 In regard to the prevention of clinkers by keeping the contents of the producer in motion, that solution was adopted in the Kitson producer ten or twelve years ago, by means of an inclined grate which was made to revolve slowly. As a result the contents of the producer were kept moving up and down, and at no time did any clinker form. The producer was discontinued, but for other reasons. The inventor of that apparatus based it, he said, on the idea that running water would not freeze, and that in the same way, any substance would be prevented from solidifying by keeping it in continual motion.

3 It must be remembered that in the operation of gas engines, the calorific power of the gas produced is not the essential thing, but rather the value of the charge actually delivered to the cylinder; and this can be made almost anything which may be desired, the proportion of air being regulated according to the richness of the gas so as to give a charge of practically constant heating value.

E. N. Trump. In making tar-free gas all of the valuable by-products are destroyed. If Mr. Bibbins proceeds to burn up the by-products from the gas in the centre of his producer, he will lose from 80 to 90 lb. of sulphate of ammonia per ton of coal, which would pay for a large part of the coal used in his producer, if it were recovered.

2 As to continuous operation: We have had one plant burning from 150 to 155 tons of coal per 24 hours, in continuous operation for the past ten years; the pressure has never been off that plant but once, and then for a period of two hours.

3 If the fuel bed in the producer is agitated, and plenty of steam provided, clinkering is almost entirely prevented. Agitation can be produced by continuously extracting the ashes at the bottom, thus uniformly loosening the bed. Even with a very deep bed almost no poking is required.

4 Our experience has been with Hocking Valley coal, which will not coke. With coking coals it is more difficult to prevent the clinkering, but the agitation by the special mechanism for removing the ashes prevents clinkering to a great extent.

H. F. Smith. While it is of advantage to run continuously, still in most plants it is desirable to start and stop the engines. The majority of manufacturing plants run from eight to ten hours a day, and it is of equal importance to be able to shut the producer down, and to start up again in the morning with a reasonably uniform con-

dition of operation, within thirty minutes, say, of starting the plant. Whether or not the type of producer outlined here is adaptable to meet that condition is open to question.

George D. Conlee. I would like some information regarding the possibility of naphthalene formation by the gas producer. In coke-oven and coal-gas practice, if the heats are sufficiently low to prevent the formation of naphthalene, an excessive production of tar results. Either the one or the other will be present.

2 Regarding the possibility of removing sulphur from gas by reheating, in the manufacture of enriched water gas for illuminating purposes, the gas is passed through checker brick heated to about 1600 deg. fahr. The gas is then scrubbed with water, cooled and passed through iron oxide to remove the hydrogen sulphide. The passage of the gas through the checkers seems to have no effect on the hydrogen sulphide, though it may change some other sulphur compounds to the sulphide.

The Author. In presenting this paper I have had misgivings that it would be considered by some as unduly optimistic. But I hope that I have been absolved from that charge through the simple showing of facts as complete as were at my command.

2 The producer under discussion is more or less the culmination of experiments of many years on different types. It represents the work of a number of engineers who have all striven for the perfection of the bituminous type in one form or another, and I feel safe in saying that the results are such as to give us some encouragement that the problem of gasifying bituminous coal is not as hopeless as it has been supposed to be.

3 First let me define what is meant by continuous operation. While I think no commercial plant should have to shut down every fifth day to clean out, yet 365 days for the plant does not necessarily mean 365 days for the producer. Taking conditions such as normally exist in an electric light plant using steam boilers, we should expect a producer unit to run at least as long without excessive labor charge for cleaning and recharging. A small percentage of reserve equipment is always essential, but 100 per cent is certainly not required.

4 If the producer is to stand by itself, there is no occasion for especial leniency, i. e., we should demand from the designers a grade of service equal to that rendered by present steam plants, and from present indications this can be obtained.

5 These high rates of combustion—30 to 50 lb. per sq. ft. grate area mentioned in the discussion—are interesting, but it must be borne in mind that sometimes the amount of coal fired includes the additional fuel for building new fires. It is apparent from the Norton test that a very considerable proportion of the total coal fed into the producer was withdrawn at the end of a normal run, and if the heat equivalent of this fuel be deducted the rate of combustion will be lowered considerably. So, in comparing intermittent and continuous types of producers, it is necessary to take this extra fuel into account, for in the case of very frequent recharging the net loss is high.

6 The size of producer mentioned by Professor Fernald is rather extraordinary. I think not many of us realize that 3000-h.p. producers are being built. If it was a two-shell producer (the two rated as a simple unit) it should hardly be compared with the single shell producer on the same basis.

7 The sensitiveness of the balanced draft method of control has, I think, been overestimated by Mr. Chapman. While it is stated in the paper that the two control valves should be permanently set, I presume it would be recognized that these valves are put there to correct any inequalities or deficiencies in the fuel bed. When the producer is properly operated the valves need little or no adjustment, otherwise they must be adjusted occasionally.

8 I do not quite agree with Mr. Chapman's statement that it is impossible to maintain uniformity of the fuel beds with hand firing. When the plant illustrated was visited I noted this point especially by the aid of a simple apparatus. This is a double poker, consisting of a section of pipe with a solid rod through the center. By shoving both down into the fire and pulling out the rod and covering the pipe with a glass at the top, the condition could be noted. It was interesting to see that when the top of the fuel bed appeared practically dead, just under the surface it was at the proper temperature. I did not find the irregular conditions of fuel bed which Mr. Chapman mentions and I do not think it was merely a coincidence. The tendency towards short circuiting which he fears in large producers is not as marked as might be expected, excepting with wet peat, possibly owing in part to conditions.

9 As to the sulphide which Professor Rautenstrauch mentions, I can only say that it has not to my knowledge caused trouble. I have seen engines running successfully for a time on by-product coke-oven gas where it was found that by keeping the rods as hot as possible the deposition of sulphur was avoided and the consequent

corrosion of the rods. As far as I know napthalene has not created similar trouble. A napthalene formation is characteristic of the distillate process where the higher hydro-carbons form the greater percentage of the heat value.

10 It is encountered in by-product coke-oven gas to some extent. But the difficulties arising from deposition of napthalene seem to be confined to delicate measuring instruments rather than the engine valves or rods which seem to be at a temperature sufficient to dissipate the accumulation. In producers the heats are run well above the destructive point.

11 Mr. Smith seems uncertain as to the possibility of the producer under description retaining its condition over periods of daily shutdowns. Table 1 shows a period of 18 days—432 hours—during which the producer was entirely idle for 23-hour periods. After a night's shutdown 15 minutes usually suffices to bring the fire into normal temperature conditions.

12 The automatic variation in the proportion of air and gas to the engine according to the richness of gas delivered to it is a problem of engine design relating to regulation of mixture. Designers must face the possibility of variations in gas from the best producers, and I do not believe any mechanical agitation of the fuel bed will avoid this necessity. In a plant employing a 15,000-ft. mixing holder I have observed a puff of rich gas (liberated just after charging) make its way clear through to the engine at regular intervals quite destroying the mixture for the moment.

13 Mr. Trump assumes that the breaking up of hydrocarbons occasions a serious loss of efficiency not encountered in the generators of tar-laden gas. Just what are the precise reactions seems to be unsolved, but in the last analysis only one factor is uppermost—the comparative efficiency of the two systems. I doubt that much over 70 per cent is obtained from either process and less when the power consumption of tar extracting auxiliaries is taken into account.

ECONOMICAL FEATURES OF ELECTRIC MOTOR APPLICATIONS

By Charles Robbins,[1] East Pittsburg, Pa.

Non-Member

The principal object of this paper is to show, by figures and curves, based upon actual tests and investigations of existing installations, how a problem in motor drive can be handled in order to show its maximum economy. It will endeavor to show that the hourly cost of operation is dependent upon the characteristics of the various types of machine tools, from the standpoint of power and time required. The load and time factor of the tool will be taken into account and the influence of this factor on the cost of production. Data are also given upon the electric-motor equipment of machine tools, with suggestions for its standardization.

2 There are certain types of tools in which the operations to be performed require constant speed, for which service the constant-speed type of motor should be used. Other types of tools call for a cycle of duties, in which the range of speed may vary almost from minimum to maximum conditions. In these cases the adjustable-speed type of motor should be used for the greatest economy. There are, therefore, in a single shop two distinct service conditions calling for different types of motors, different methods of applying the motors to the tools, and different methods of control.

3 Where direct current is available, these conditions can be met by the direct-current motor, i.e., both a constant-speed and an adjustable-speed motor is available for machine-tool work. On the other hand, the alternating-current motor is essentially a constant-speed machine. At the present time no commercial method has been found for varying the speed of an alternating-current motor in such a way that it can be

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successfully used for machine-tool service. Thus it is apparent that the machine-tool designer must take into account not only the application of the motor to the tool, but also the class of current supply available in the manufacturing establishment in which the tool is to be used.

4 An alternative method of driving is by the use of a system of gears, commonly called a gear box, driven by a single belt considerably larger than that ordinarily employed on cone pulleys. This large belt will to a considerable extent furnish the power required, the necessary changes in speed being obtained by changing the gears. Obviously, however, a gear box arrangement cannot be as convenient of manipulation as a motor controller, which can be mounted in a position to be easily reached by the operator. In addition to this difference between the two methods of changing speeds, the motor drive offers finer gradations of speed; that is, if the same results were obtained in a gear box, the multiplicity of gears would be considerable, and the up-keep a matter to cause serious consideration.

STANDARDIZATION OF TOOL EQUIPMENTS

5 One of the great drawbacks to a harmonious design of motor and tool has been the lack of a proper understanding of the joint problems of the motor and tool builder, this condition showing the necessity of some standard in respect to speeds or speed ratios, method of control, and certain dimensions of the motor or its adaptation to the tool. There is also a lack of standardization of the method of supplying power in industrial plants. For instance, there are so-called different systems, as direct current of 110, 220 and 500 volts, and alternating current of 220, 440 and 550 volts and two or three phases; also either 25 or 60 cycles may be called for.

6 In view of the above conditions, which are in a measure arbitrary, the future developmentof the art will be materially benefited if some standardization can be adopted by the tool builder and the motor builder, whereby they may be able to recommend certain standard power equipments for metal-working establishments.

STANDARDIZATION TO ACCORD WITH CENTRAL STATION SERVICE

7 Central station power companies now realize the great advantage of a day load and are quoting low power rates to manufacturing establishments. It seems probable that in the future much of the power for small, and to some extent for large, manufacturing estab-

lishments will be furnished by central power companies, either those which are formed for the purpose of furnishing power only, or those which are regularly organized as public utility companies, furnishing both power and light. To this latter type of existing central power stations the day load supported by power service to manufacturing establishments is particularly attractive.

8 As most communities contain both manufacturing plants and central station companies, we look forward to an immense dev lopment of central power service, to be used by large manufacturers as well as by the smaller ones. For this reason we suggest that the class of service, i. e., the characteristics of the current supply, should be taken into account when making standards for the operation of metal-working tools.

9 The steam railroad companies as a class have been to a considerable extent the largest single purchasers of machine tools, and it is well to consider the power requirements of such classes of purchasers when deciding upon a standard of motor equipments for tools.

10 For some years it has been the almost universal practice of steam railroad companies to install alternating-current generator equipment in their power stations; these are principally of the turbine type, largely for the reason that their requirements are to a considerable extent similar to those of the central stations of power companies. They are called upon to distribute current for lighting their train sheds, stations and yards, and power for operating turn-tables, transfer tables, etc., and for the operation of their repair shops, which usually consist of machine and wood-working divisions. Because of the simplicity and the great desirability of alternating-current motors, the railroad companies have adopted them almost exclusively for constant-speed service, as exemplified in the machinery of their wood shops, and for miscellaneous power purposes, such as pumping, operation of fans, driving incidental sections of line-shafting for supplying power to the smallest types of tools, on which it would be inadvisable to employ individual motors, and to tools requiring constant-speed motors.

11 For tools whose operation calls for adjustable speed, the standard practice is to employ direct-current adjustable-speed motors, using a controller conveniently located to the operator in such a way that the variation from minimum to maximum speed can be made with great facility, therefore affording a ready means of obtaining the maximum output for which the tool is designed.

12 It will be evident from this practice that two kinds of current are employed—alternating current for the primary and direct current

for all secondary operations. To transform from alternating current to direct current, either a rotary converter or a motor-generator set is employed, the specific selection of one or the other depending somewhat upon local conditions and the class of supervision available for the operation of the outfit.

13 The same scheme of operation can be very advantageously employed when using central station service for the operation of machine shops or metal-working establishments in which machine tools are employed. Such a standardization of tool equipments by the tool builders and the motor manufacturers would tend to place the operation of metal-working tools on a more economic basis, in that it would enable better tool equipments to be designed with a definite certainty that the motor requirements could be forecasted. As it is now, a very considerable risk is involved in designing tools in advance of orders. Few companies manufacture motor-driven tools in large quantities and the public is thus called upon to pay a higher price because of a lack of standardization.

14 On account of the fixed conditions of central station service, it is almost universal for the service to be 60-cycle, 3-phase, and as the transmission line is of relatively high voltage, transformers will be necessary at each industrial plant, and the voltage of the motor installation can thus be suited to the requirements. In metal-working establishments, where the motors can be located on the tools, or to some extent in close proximity to the metal structure, it is desirable to use a relatively low potential, say 220 or 440 volts. Thus in a measure there has been established automatically a standard for alternating-current service, consisting of 60-cycle, 3-phase, 220-440-volt, this standard being that used by most of the largest single purchasers of metal-working tools, i. e., the steam railroad companies.

15 By the adoption of standards which conform with the central station supply service, it is evident that even in the case of very large manufacturers who have their own isolated power plants, use can be made of a so-called break-down connection with the central station power company, as an extra precaution to insure continuity of service. This break-down connection can be made available only when the service supply is uniform with that employed by the isolated plant. Connection to a central power company would prove a very great advantage to a manufacturer for overtime work, when but little power is usually required, or under conditions when but a small percentage of tools are in operation as it would permit closing down the isolated plant, and the operation of the limited service from the outside power system.

16 This standardization of tool equipments would also enable existing manufacturing plants not equipped throughout for electric driving, but requiring the service of machine tools, to make trial installations of motor-driven tools or of a rapid-production tool, in which much of the advantage to be gained is due to the motor drive.

ANALYSIS OF OPERATING CONDITIONS

17 It is only recently that data have been available to show beyond doubt the intermittent operation of the average machine tool. When a machine shop is driven by a belt from engine to lineshaft, and from lineshaft to machine tool, it is difficult to determine with any degree of exactness the length of time any particular tool is in operation, or the average time of operation during the working day.

18 With the installation of motors on lineshafts, it became evident that the total horsepower capacity of motors was much in excess of the power generated in the power station. This ratio is sometimes three to one, other times possibly four to one.

19 As individually driven tools are adopted it is noticed that the total horsepower capacity of all the motors connected to the service grows very rapidly, and that the ratio of the connected capacity to the power supplied is often as high as five or six to one, indicating that the time-load factor of the average machine tool is relatively low.

20 This apparent difference between the connected capacity of motors and the demand on the power station has led to a careful analysis on the part of the motor builders to determine exactly the length of time tools can be expected to be in operation..

21 An analysis which took into account the time of loading, cutting, unloading, and other delays occasioned by miscellaneous causes, showed conclusively that it was not necessary to use a continuously rated motor; in fact, an intermittent rating on the motor for a period not exceeding two hours' continuous service answers for almost all kinds of machine tool applications. This knowledge enabled the motor manufacturer to build a more economical motor, one of smaller size, and consequently reduce the expense of applying motors to machine tools. The present-day tool equipment ought not, therefore, to be much more expensive, if any, than that of the belt-driven tool, when the cost of belting, shafting and power house equipment is considered.

22 When machine tools are equipped with individual motors, a graphic recording meter may be connected in the motor circuit, making it possible to have a complete log of the operation of the particular

tool during its time of service. The chart furnished by the graphic meter will show the time of loading and unloading the tool, the time of cutting, all delays due to stoppage for one cause or another and the amount of power to operate the tool, which is a direct function of the work done.

23 Fig. 1 shows a graphic recording meter by which interesting tests have been made in studying machine tool operations. The instrument is unlike an indicating meter, in that instead of a needle

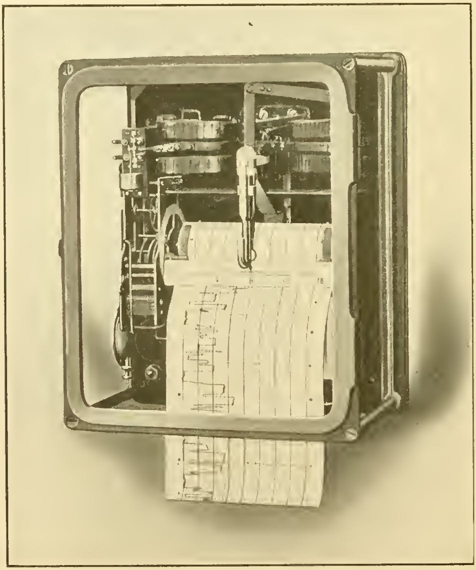


Fig. 1 Graphic Recording Meter

passing over an indicating scale, the meter is provided with a pen moving horizontally, thus making a line on a properly graduated roll of paper. The paper is moved by clockwork, vertically, and at right angles to the pen, so that a permanent record of the magnitude and time of all operating changes is obtained.

24 A time study can be made from each tool from these charts, and knowing the theoretical time for the job an analysis can be made of the

curve, furnishing information that will enable the foreman to increase the productive capacity by the elimination of delays. He will also know whether or not the tool has been working at its maximum capacity, whether the tools have been kept up to standard conditions, and in general can apply the necessary remedies.

The Economics of Motor Drive as Determined by the Actual Performance of the Tools

25 The economy of the individual motor drive, due to the fact that practically the exact cutting speed can be obtained for any operation, has been pointed out. This economy is not so important, however, as that of keeping a tool in continuous operation through longer periods of time, by reducing the time required for handling and other avoidable delays, as previously mentioned.

26 The accepted method of capitalizing motor drives seems in general to be on the basis of the incidental savings in the workman's time. In our opinion this is not the whole story by any means. When determining the monetary advantage of motor drive, the value of time saving should be considered on the basis of its effect on the total cost, which includes the workman's labor and the investment cost per hour of the tool.

27 In addition to workmen's wages, every shop has the following expenses:

a Interest and depreciation on cost of buildings and accessories.

b Repairs and renewals to existing equipment.

c General operating expenses, including losses due to defective workmanship, design and material.

d Salaries of supervisors, engineering staff and clerks.

28 These overhead charges must be included in the cost of any manufactured article. A method frequently employed is to determine from time to time the percentage which the total overhead charge bears to the cost of total actual or productive labor. This percentage in large shops reaches from 100 to 200 per cent, or even more. The total labor charge is then obtained by multiplying the actual labor cost by one, plus the per cent to be added for the overhead charge.

29 This is an easy way to take care of the overhead charge; but the method is inaccurate and does not show the relative importance of different types and sizes of machines. This statement is especially true where a great variety of materials is manufactured, in shops using a

large number of different types and sizes of tools. Under such conditions, the precentage obviously varies within wide limits for different kinds of work.

30 A satisfactory method of distribution is to set off against each tool its proportion of the total overhead charges. The portion chargeable to each tool depends entirely on local conditions; and thorough amiliarity with these conditions is needed in order to apportion these charges equitably. In this way, the relative importance of each machine is taken care of.

31 In a shop where only one type of article is manufactured, and the castings are passed from one machine directly to the next, a simple and logical way is to divide the total overhead charge among the tools, in proportion to the floor space charged to each tool. In the majority of shops, however, the above simple condition does not exist; several sizes and kinds of articles are usually turned out, and various sizes and types of tools, differing greatly in their operating characteristics, are employed. In such cases, not only must the floor space be considered, but also the time each tool is actually in operation, the nature of the work and the amount of supervision and engineering attention needed.

32 Large shops handling different classes of materials are in most cases divided into various departments or sections, and each section may be considered as a separate smaller factory. The overhead charges against each department may thus be apportioned among its tools in proportion to the floor space occupied, making proper allowance for special local conditions, or special supervision or engineering attention. Here again is required thorough familiarity with both the engineering and the shop features of the materials manufactured.

33 In our experience we have found the overhead charges to be approximately as follows:

Variable charges	from 50 to 55%
Salaries	from 25 to 30%
Interest on cost of machine tools	from 5 to 10%
Depreciation on cost of machine tools	from 5 to 10%
Fixed charges	3%
Power	from 1 to 2%

The detail method of arriving at these general figures is found in Appendix 5.

DEFINITIONS OF TERMS

34 In discussing the economics of motor drive there will be a number of terms used which are here given with our interpretation of their meaning.

Applied to the operation:

Time factor = ratio of actual cutting time to total time required to complete a machining operation

$$= \frac{\text{Actual cutting time}}{\text{Total time to complete operation}}$$

Applied to a Machine Tool:

$$\left.\begin{array}{l}\text{Time factor}\\ \text{in per cent}\end{array}\right\} = \frac{\text{Total daily actual cutting time in hours}}{\text{Total number of working hours}} \times 100$$

Average running load=average input to motor while operating, usually expressed in kilowatts, but may be expressed in percent of full load input.

For rough calculations in this paper the input of a motor in kilowatts is assumed to be the same as the output in horsepower; that is, the motor efficiency in all cases is assumed to be about 75 per cent. This low percentage will take care of the fact that motors operate at light loads a considerable part of the time.

Maximum load = maximum input to motor, expressed in same terms as the average running load.

Average load = *Average daily load* = average input to motor during the total working hours; usually expressed in kilowatts. This load multiplied by the total number of working hours gives the total kilowatt hours consumed per day, and is the basis of payment for energy. The average load multiplied by the number of hours per day and by the price per kilowatt-hour gives the cost of energy per day. The average load also equals the average running load multiplied by the time factor.

Load factor = the ratio in percent of the average daily load to full load rating of the motor, or

$$\text{Load factor} = \frac{\text{Average daily load}}{\text{Full load rating of motor.}}$$

CONDITIONS ENTERING INTO THE OPERATION OF A MACHINE TOOL

35 In order to obtain a maximum output from a machine tool, a careful analysis must be made of all the conditions entering into the operation of the tool. One method of doing this in the case of a motor-driven tool is to take power readings at frequent intervals and lay

these out on a chart basis. Another and a much more convenient method is the employment of a suitable meter, as already described, designed to make a graphic curve, showing the exact condition occurring in the service when such a meter is applied to any motor-driven tool.

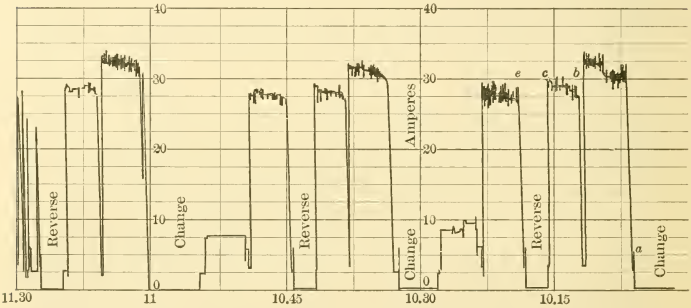


Fig. 2 Meter Record when Turning Shafts Shown in Fig. 3

36 Fig. 2 shows a record obtained while shafts of the dimensions shown in Fig. 3 were turned from machinery steel. Both Fig. 2 and Fig. 3 are lettered for reference. The records read from right to left, as indicated by the time at the bottom of the curve in Fig. 2. The vertical coördinate is in amperes, the full scale being 50 amperes. This cur-

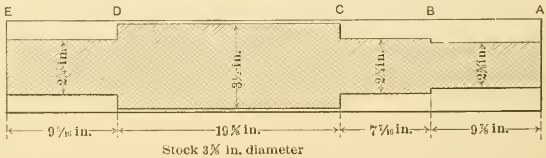


Fig. 3 Shaft of Machinery Steel

rent at 220 volts corresponds to 11-kw. input to the motor. At the extreme right, the record indicates zero power; that is, the motor was standing idle.

37 During the interval marked "change," the stock to be turned was placed in the chuck of the lathe. At *a* the current increases for a

very short interval to about 3 amperes, while the lathe was running idle. The current then suddenly increases to about 30 amperes, due to the fact that the cutting tool was fed against the stock and the cut started. The current remains at this value for a period of about five minutes while the cut *AB* is taken, changing the diameter of the stock as indicated in Fig. 3. At *b* the current drops to three amperes, the motor running idle while adjustments of cutting tools are made. The current then increases to 28 amperes while the cut *BC* is taken. At *c* the machine is stopped to reverse the half-completed shaft for machining the opposite end. At *e* the machine is again started and the current increases to 27.5 amperes while the cut *ED* is taken. Another adjustment of the diameter is then made, the machine running idle for a short interval. From 8 to 10 amperes are required when the final cut *DC* is taken, after which the machine is stopped to remove the completed shaft. A similar cycle is repeated when the next shaft if turned.

38 The record shows three completed cycles, covering the time required to complete three shafts At 11.15 a.m., before taking the cut *ED*, there are sudden fluctuations of current; the form of the curve compared with other cycles shows clearly that some trouble was encountered with the cutting tool or work, and the adjustments made. The record also shows the delay in time.

TABLE I. ANALYSIS OF TIME AND POWER OF A LATHE OPERATION

Shaft	Time	Mins. Amps.	Cutting				Mins. %	Total Cutting	Change	Reverse	Adj. Tool	Misc.	Comp.	Time Factor	Load Fact.
			AB	*BC*	*ED*	*DC*									
1	7.30	Mins.	5.1	3.7	4.9	4.9	Mins.	18.6	5	5	12.0	21.2	61.8		
		Amps.	23	22	22	5	%	30	8.1	8.1	19.5			30	12
2	8.05	Mins.	5.3	3.9	4.4	4.4	Mins.	18.0	4.7	2.4	4.4		29.5		26
		Amps.	25	23	24	5	%	61	15.9	8.1	14.9			61	
3	8.30	Mins.	5.0	3.7	4.8	4.6	Mins.	18.1	7.5	2.4	1.9		29.9		
		Amps.	29	25	24	7	%	60.5	25	8	6.4			50.5	26.5
4	9.05	Mins.	4.5	3.4	4.8	4.7	Mins.	17.4	3.2	8.9	2.3	27.1	31.8		
		Amps.	31	29.5	24	6	%	54.8	10	27	7.2			54.8	25
5	10.05	Mins.	5.1	3.8	4.5	4.7	Mins.	18.1	5	2.5	1.3		54.0		
		Amps.	29	26	25	6	%	33.5	9.3	4.7	2.4			33.5	14.6
6	10.30	Mins.	4.9	3.6	4.6	4.9	Mins.	18.0	4.3	2.4	2.0		26.7		
		Amps.	28	25	25	5	%	67.5	16.1	9	7.5			67.5	25
7	11.00	Mins.	5.0	3.7	5.4	5.1	Mins.	19.2	5.5	2.6	2.7		30.0		
		Amps.	29	26	24	4.5	%	64	18.4	8.7	9			64	27

39 Table 1 is a summary of the data obtained from the graphic record, part of which is shown in Fig. 2. Observations of cutting

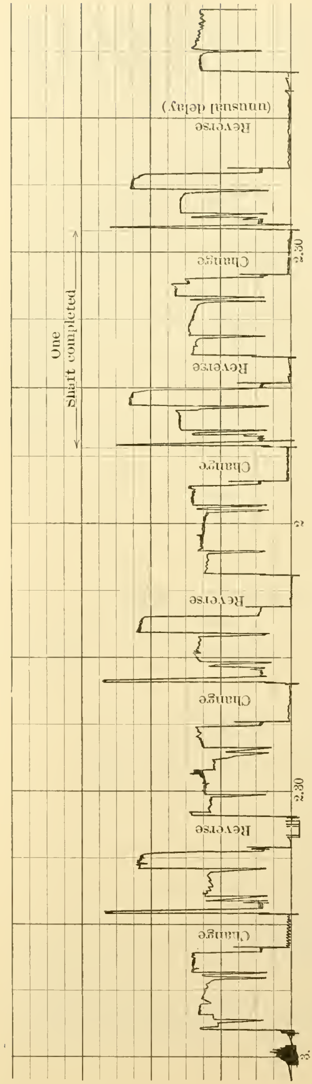


FIG. 4 RECORD MADE WHEN TURNING A LIGHT SHAFT WHICH COULD BE PLACED AND REMOVED BY HAND.

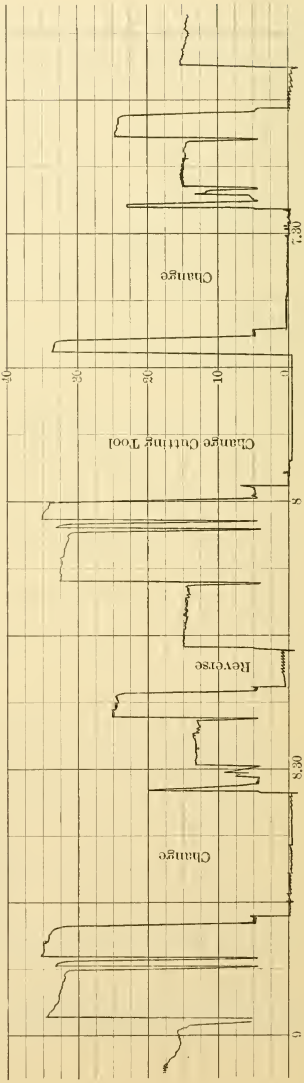


FIG. 5 RECORD MADE WHEN TURNING A HEAVY SHAFT WHICH REQUIRED A CRANE FOR HANDLING

speed and feed were taken at the lathe. The cutting speed used while turning these shafts was 55 to 60 ft. per min. The feed while taking the cuts *AB*, *BC*, and *ED* was 0.04 in. per revolution, and while taking cut *DC* was 0.077 in. per revolution. The normal time to complete a shaft was from 27 to 32 min. In case of shaft No. 1 the time was 62 min.; this was the first shaft turned after starting work, and preliminary adjustments, oiling lathe, etc., consumed 21 min.; 12 min. were required to adjust the cutting tool. In the case of shaft No. 5, 54 min. were required on account of a 27-min. delay. The amperes referred to in Table 1 are those below the 3 amperes required to run the machine idle; they are, therefore, a measure of the power required to remove the metal. The time factor averages 53 per cent; its maximum value is 67 per cent, and its minimum value is 30 per cent. The load factor is 25 per cent under normal conditions.

40 It must be obvious that, with a given rate of cutting, the fewer the delays, the higher will be the time factor. The magnitude of the records is an indication of the rate of removing metal, as will be further explained.

41 By means of this meter record it is possible to discover all delays, and to check the rate of cutting metal. Those are the two fundamental factors which determine the rate of output on machine tools. Any deviation from the standard cycle of operation is at once detected from the form of the record. Observations of cutting speed and feed need be taken in only one case. The record will not only show the deviation therefrom, but will also indicate whether the modification is an improvement or a drawback to the rate of output. Fig. 4 and Fig. 5 show two records taken on the same roughing lathe, operated by the same man, but turn'ng two different shafts. The shaft turned while making the record shown in Fig. 4 was light, and could be removed and replaced in the lathe by hand. That turned when the curve in Fig. 5 was obtained was heavy, and required crane service. The greater intervals between cutting operations, so apparent in the case of Fig. 5, were due to delays in obtaining crane service to handle the heavy shaft.

42 Records taken during several days of operation showed an average of 5 min. longer time required for every change and reversal when made by crane. This condition was remedied soon after making the test, by installing a jib crane next to the lathe, and the time to complete the larger shaft was thereby reduced from 55 min. to 45 min., a saving in time and cost of about 20 per cent. The overhead charge against this tool (see Appendix 5) was 60 cents per hr., or $6 per 10-hr. day. The operator received $3.50 per day, making a total daily

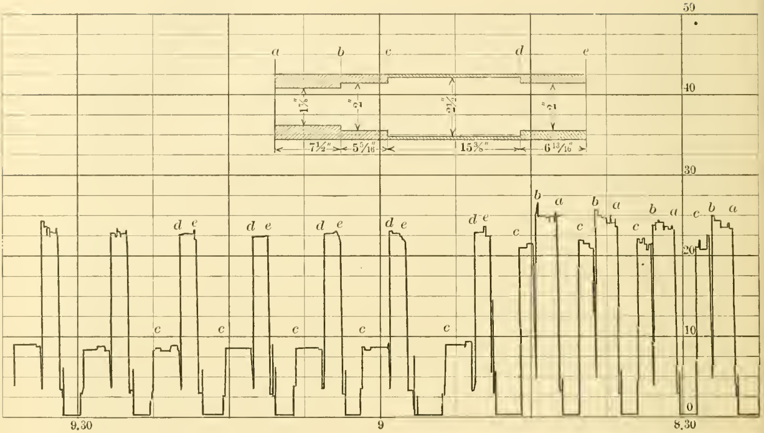


Fig. 6 Record when Turning the Shaft Shown in this Diagram

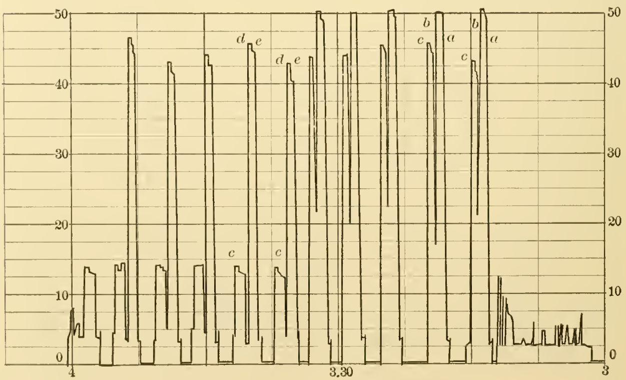


Fig. 7 Record when Turning the Same Shaft at Double the Cutting Speed

expense of $9.50. Before the jib crane was installed ten shafts were completed per day, making the cost of actual labor and overhead tool charge $9.50 divided by 10, or 95 cents per shaft. After the improvement, 12 shafts per day were completed with the same overhead charge, thus reducing the labor and overhead tool charge to 79 cents per shaft.

43 Such a delay seems self-evident, after it has been discovered, but in a large shop where everybody is busy small delays are easily overlooked. An automatic recording meter reveals delays caused by grinding and replacing tools, etc., besides those just indicated.

44 The elimination of delay, however, is not the only advantage to be obtained from the use of a recording meter. Fig. 6 and Fig. 7 are meter records which show rates of cutting on a shaft with the dimensions given in Fig. 6. In Fig. 6 the cutting speed was 50 ft. per min. The feed for cuts *AB*, *BC* and *ED*, was 0.05-in. per revolution, and for *DC* was 0.072 in. per revolution. The same feed was employed for corresponding cuts in Fig. 7, but the cutting speed was 100 ft. per min. It will be noted that the current above friction load in Fig. 7 is double that required for similar operations in Fig. 6. The saving in time is clearly shown. An analysis of records of this kind, taken over a period of several days, gives a means of determining the most economical feeds and cutting speeds to employ on a given operation.

TABLE 2. TIME FOR ROUGHING SHAFT, EXTREME CONDITIONS

	Average Condition		Best Conditions		Poorest Conditions	
	Minutes	Per Cent of Total Time	Minutes	Per Cent of Total Time	Minutes	Per Cent of Total Time
Removing and replacing shafts	6.0	38	2.8	23	14.9	50
Adjusting tool	1.7	11.0	1.4	12	6.7	22
Cutting	8.0	51.0	8.0	65	8.4	28
Total	15.7	....	12.2	....	30.0	....

45 Table 2 shows the time relation between the various operations in roughing the shaft, outlined in Fig. 6. Approximately the same conditions were found with shafts of other characteristics. The time factor of lathe operation for this class of work is thereby shown to vary from 25 to 65 per cent, the average being about 50 per cent.

46 An investigation by personal observations over a short period of time often leads to erroneous results, as is shown by the following

experiments: In turning shafts on a roughing lathe, the first trial was with a cutting speed of 80 to 100 ft. per min., and a feed of 0.026 to 0.044 in. per revolution. In the second case, a cutting speed of 40 to 50 ft. per min. at a feed of 0.05 to 0.07 in. per revolution was employed. A single job could be completed in either case in 16 min., 12 min. being required for cutting. However, the average time per shaft, during several days operation, was 22.6 min., with the higher speed, and 21.6 min. with the slower speed. The same number of cubic inches of metal per minute was removed in each case; but with the higher speed, more frequent regrinding of tools was necessary, resulting in more delays and giving the lower speed five per cent advantage in time saving.

SUMMARY OF THE USES OF THE GRAPHIC RECORDING METER

47 By means of the graphic recording meter, the following improvements in shop management can be effected:

- *a* If individual motors are used to drive machine tools, the exact percentage of total working hours consumed in actual cutting can be determined; it is found to average from 40 per cent to 50 per cent, the maximum being as high as from 60 per cent to 65 per cent where the cut is of long duration; the minimum from 20 per cent to 30 per cent where jobs are short and the delay long in waiting for material, drawings, etc.
- *b* The meter reveals all delays and suggests measures for eliminating those not essential and reducing all others to the minimum, thus materially increasing the time factor. All delays shown should be accounted for, and an attempt made to avoid them. Common delays are in assignment of the next job, in obtaining drawings, tools and other necessary materials, and in waiting for crane service.
- *c* The rate of cutting indicated by the power consumption of motor-driven tools can be checked with a recording meter. The maximum rate is limited only by the nature of the work, the strength of the machine tool and of the cutting tool.
- *d* The rate for maximum economy can be determined for different classes of work; and the records, considered as standard, can be compared with other operations of the same

character to see whether the proper rates of cutting were used. In a finishing operation the rate depends upon the accuracy required. A record can be made while an expert machinist does the job, and this record should be referred to when other jobs of similar character are machined.

48 By the use of curve-drawing meters, and a careful study of the data obtained, the superintendent of a shop in which the individual motor-driven system is employed can set a limit fair both to employer and employees, for roughing, finishing, adjusting and setting-up. Different methods of doing the same job can be compared to determine which is the most efficient.

49 The graphic meter need not be located near the machine to which it is connected, but may be placed in the foreman's office. Small leads connected to a shunt, or to a series transformer, according to whether direct current or alternating current is employed, are all the wiring required. The wiring can be so arranged that the connections of the meter can be readily transferred to any one of several tools; thus a single meter can be made to serve a group, or any number of tools, depending somewhat upon the frequency with which the records are required.

50 So far we have dealt chiefly with the time required to do machining operation, time being a most important consideration with shop managers and those who use machine tools. The power consumption, however, is also of some importance, especially to those requiring motors for machine tool operation.

RELATIVE ECONOMY OF LINESHAFT DRIVE AND INDIVIDUAL MOTOR DRIVE

51 An increase in economy of operation of manufacturing machinery can be effected in two ways: first, by reducing the power required to operate the machinery, by saving of friction load, etc.; second, by reducing the time required for a given operation, or, in other words, increasing the output in a given time. When confronted with the problem of deciding between the continued use of an existing lineshaft drive, or an individual motor drive, or when deciding between the two methods for a new installation, the problem should be considered in all its phases, as outlined in Table 3. This table includes every important item to be considered, except one; and in every case the advantage is with the motor.

52 Comparing the first cost is possibly the first consideration to enter the mind of most men, and this is the one consideration omitted from Table 3. That this consideration is relatively of minor

TABLE 3. COMPARISON OF LINESHAFT DRIVE AND INDIVIDUAL MOTOR DRIVE FOR MACHINE TOOLS

Item	Lineshaft Drive	Individual Motor Drive	Advantage of Individual Motor
1 Power consumption....	Constant friction loss in shafts, belts and motor, power for cutting	Friction loss (motor and tool only); useful power only while working	Less power required
2 Speed control...........	No. speeds = no. cone pulleys × no. gear ratios	No. speeds = no. controller points × no. gear ratios	More speeds possible; time saved in speed adjustments
3 Reversing..............	Clutch and crossed belt	Reversible controller	Time saved in reversing
4 Adjusting tool and work	Stopping at any definite point, very difficult	Can be started in either direction and stopped promptly at any point	Time saved in setting up and lining up
5 Speed adjustment......	Large speed-increments between pulley steps	Small speed increments between controller steps	Time saved by obtaining proper cutting speed
6 Size of cut..............	Limited by slipping belt; large belts hard to shift	Limited by strength of tool and size of motor	Time saved by taking heavier cuts
7 Time to complete a job..	....	....	Much less time required as indicated for previous items
8 Liability to accidents	Slipping or breaking belts; injury to machine tool; cutting tool or prime mover	Injury to machine tool, cutting tool or motor	Much less liability to accidents
9 Checking economy of operations	Close supervision required: very difficult to locate causes of delay	Accurate tests possible by means of graphic meter which records automatically all delays and rate of cutting	Causes of delay and remedies easily located without personal supervision
10 Flexibility of location..	Location determined by shafting, and changes difficult	Location determined by sequence of operations; changes readily made	Greater convenience in handling and increased economy of operation; more compact arrangement possible

importance will be evident, when the saving in power consumption, and in time, made possible by individual motors, has been considered.

SELECTION OF MOTOR AND TOOL EQUIPMENT

53 In the selection of a motor-driven tool, there are certain features which should be taken into account and properly analyzed, and specifications drawn to cover them. If a tool is for specialized manufacturing, there should be specified:

a The exact class of work which the tool is to accomplish.

b If the power required to remove the metal is not known, then a statement should be made as to the approximate feed and cutting speeds to be taken.

c Careful analysis should be made of the time required to load and unload the machine, to determine the feasibility of employing auxiliary means other than manual labor for loading the tools.

d From this information, an approximate determination can be made as to the intermittency of operation of the tool, in order to decide whether an intermittently rated motor or a continuously rated motor will be required.

e By a knowledge of the physical shape of the work, determination can be made as to whether an adjustable-speed motor will result in economy of time, if used on this particular class of tool.

f Will enable the tool builder to determine upon the proper type of controller, and its most desirable location from an operating point of view for the workman.

54 If a special type of tool is not desired and it is preferable to purchase one with such characteristics that it can be used for general manufacturing, one should determine as nearly as possible the range of material or work for which it will be used in straight manufacturing operations. A knowledge of this will undoubtedly permit of a better motor and tool selection, than the simple purchase of a standard stock tool.

55 It should be realized that under present schemes of operation few tools are in operation more than 50 to 60 per cent of the time, whereas, the load factor of those tools may be as low as from 10 to 40 per cent. Thus we have it brought home to us clearly that much of the time the tool is in idleness and is often operated much less than its maximum capacity.

56 The direct-current motors are built for speed adjustment over a range of 1 to 2, 1 to 3, and in some instances 1 to 4. With the proper selection of controller the speed adjustments may be made in small increments of from 10 to 15 per cent, and since these small increments of speed adjustment are available, it is essential that a controller be selected of such type that it can be mounted conveniently to the operator, so that he may take full advantage of them.

57 Where it is necessary to employ the alternating-current motor, it may be absolutely essential to employ a gear box to obtain the various speed adjustments. When such a machine is employed, the fine gradation of speed obtainable with a direct-current adjustable speed motor is absent, and the gear box will practically take the place of the ordinary cone pulley arrangement. It has, however, one advantage when motor-driven, and that is, that the tool is supplied with positive power at all times, and will take care of the maximum conditions without slipping or loss of power, which frequently occurs when belt drive is used. In some instances it has been found possible to make good use of the so-called multi-speed alternating-current motor. This form of motor consists in certain different types of windings, permitting of a multiple method of pole grouping, such as for instance, a speed of 1800, 1200, 900 and 720 r.p.m., according to the method of winding the motor. In some cases, this type of constant-speed motor, when used in conjunction with a gear box, will permit of somewhat finer gradations of speed than are possible with a constant-speed alternating-current motor and a standard gear box.

58 While it is apparent that with the constant-speed motor all of the advantages of the adjustable-speed motor cannot be obtained, a tool equipped with either type has the advantage to be derived from the ability to obtain a graphic log of the time of operation of the tool. With either type, in combination with a graphic recording meter, a distinct gain can be made over a belt-driven tool from which such graphic curves cannot be conveniently obtained.

59 In Appendix 5, there are the segregated charges, which must in some manner be taken into account in determining the cost of a machine tool hour, not only including the workman's time, but also the actual expense to a manufacturing establishment of having a tool equipped and ready to be used when the workman requires the services of such tool. Table 2 of this appendix will show the range of the tool-hour rate, from which it is evident that it is far in excess of the labor rate for that tool; consequently, any time which can be saved in keeping the tool in its maximum productive capacity will far outweigh any

saving that can be made in the actual labor account. It is this one feature in which the motor-driven tool in combination with the graphic recording meter is destined largely to decrease the cost of machining operations when the records available by this combination are carefully studied and proper remedies applied.

GENERAL CONCLUSIONS

60 The economical operation of a machine shop requires a thorough analysis of all the operating costs; that is, overhead and operating charges of all kinds, and an accurate knowledge of the operating conditions of all machine tools. Investigations of these conditions must be conducted by someone familiar with both the engineering and the shop features of the apparatus manufactured. The investigator should also be familiar with the characteristics of the various types of motors and methods of control, in order that the most advantageous electrical equipment as well as the best machine tool equipment may be installed, with suitable tools for different sets of conditions.

61 Such investigations lead to the following improvements which result in increased productive capacity:

- *a* More flexible arrangement of tools.
- *b* Greater facilities for handling materials at the tools.
- *c* Greater facilities for handling materials between tools.
- *d* Better facilities for obtaining auxiliary material, drawings, tools, etc.
- *e* Better facilities for making adjustment of the tools during machinery operation.
- *f* Removal of causes of unsuspected or avoidable delays due to small accidents and improper characteristics of the drive.
- *g* All lost time, due to whatever cause, and which can be avoided, is immediately brought to the attention of the superintendent, and an analysis of these losses will result in their elimination.

62 With motor-driven tools this analysis can be made much more conveniently and with less expense than can similar studies with any other form of machine-tool drive.

63 While in many shops there are elaborate systems of time keeping, with time clocks, etc., all of which are based on keeping an exact record of the workman's time and seeing that he works the maximum

or full shop time, yet the most important consideration in manufacturing with machine tools is that the tools shall operate their full capacity, on account of their greater hourly value.

64 In comment on this conclusion it may be said that our tests have not been confined to metal-working tools, etc. We have found similar conditions in the wood-working industries, to some extent in cement mills, steel mills, brass and copper rolling mills, to a less extent in the textile mills, where it is a supposition that every machine is running the maximum number of hours, and at its maximum load at all times; and in several minor industries, in which the information therein contained is no less important, even though it might be different than that obtained with machine tools or metal-working tools, as ordinarily installed.

65 Certain it is, that a careful analysis and study of conditions which are conveniently possible in motor-driven establishments will greatly reduce the cost of operation, and it seems reasonable to suppose that the methods herein illustrated may serve some useful purpose if the data will arouse an interest on behalf of those present.

66 We know that wherever the tests have been made, that the conditions of operation have been very materially benefited, and feel without question of a doubt that many dollars have been saved on account of the knowledge shown by a simple record taken from motor-driven machines, which records are available to all those who have these meters.

67 The writer wishes to acknowledge his indebtedness to Mr. A. G. Popcke, who has made the tests herein illustrated, and who has supplied some of the information contained in the paper, and without whose coöperation the information herein submitted would not be available.

APPENDICES

The five appendices which supplement the paper pertain to the following subjects:

(1) The characteristics of various machine tools as shown by diagram from recording meters;

(2) Data on the power required to remove metal under the conditions set forth in the appendix, together with convenient charts for determining the various factors mentioned;

(3) A summary of the average horse power equipment for different types of tools and the approximate speeds of the motors, which

are normally selected for this work, the figures given are for average conditions only and are not applicable to the heaviest types of tools. In some instances, also, the motors called for are larger than would be used for tools of several years ago. The object of the figures is simply to indicate approximately the sizes of motors usually specified;

(4) Calculation to determine whether it is more economical to equip an old machine with a motor or to purchase a complete new motor-driven equipment.

(5) Over-head charges and machine hour rates.

APPENDIX NO. 1. POWER ANALYSIS OF MACHINE TOOLS

The results which follow were obtained from graphic meter records from certain machine tools under the conditions specified. These examples are given to show the characteristics of the power and the time factors that enter into the performance of machine tools of different types. (In connection with this Appendix see definitions of terms in Par. 34 of the paper.)

VERTICAL BORING MILLS

2 In Fig. 2 which follows is a record from a 72-in. boring mill equipped with a 220-volt adjustable-speed motor, 780 to 1560 r.p.m., 8.5 h.p. (assumed input at full load 8.5 kw.), taken while the tops of bronze discs were turned off and bored out. The vertical lines at frequent intervals show where the motor was started and immediately stopped, in order to make adjustments

TABLE 1 OPERATING CONDITIONS OF 72 IN. VERTICAL BORING MILL

Test No.	Time Factor %	Average Running Load		Max. Load		Avg. Kw. per Hr.	Load Factor
		Kw.	% Full load	Kw.	% Full load		
1	35	1.8	21	7.7	90	0.63	7.5
2	56	2.0	24	8.8	103	1.1	13.5
3	62	2.8	33	8.8	103	1.7	20.5
4	46	2.8	33	6.6	78	1.3	15.
5	28	2.2	26	7.7	90	0.62	7.5
6	37	2.2	26	8.3	98	0.81	9.5
Avg........	44	2.3	27	8.0	94	1.00	12.

by moving the table of the boring mill a short distance. The gradual decrease in power after 9 a.m., and also after 3 p.m., shows improper use of the controller. The tool was fed towards the center of the mill, thereby gradually decreasing the diameter of the work. The motor was evidently allowed to run at a constant speed, while the speed should have been gradually increased to compensate for decreased diameter of work, and thereby keep the cutting speed constant. The controller was arranged to give the required speed adjustment, and failure to take advantage of this feature caused loss of time. In one

instance the records showed that 10 min. was consumed for an operation which could have been performed in 6 min., if the cutting speed had been kept constant, a saving of 40% in this operation. In another case, the time taken was 15 min., and would have been 9.5 min. with a constant cutting speed, which would have resulted in a saving of 37%.

3 While taking roughing and finishing cuts on this boring mill, from castings of motor frames, brackets and end plates, the conditions were found to be as in Table 1, from which the following summary is obtained:

Average time factor	44%
Average running load	2.7 kw., or 27% of full load
Maximum load, sustained for several minutes	.8 kw., or 94% of full load
Maximum load peak	8.75 kw., or 103% of full load
Average load	1 kw., load factor 12%

CHARACTERISTICS OF RADIAL DRILLS

DRILLING AND COUNTERBORING

4 Table 2 was made up from records taken upon a 10-ft. radial drill driven by an induction motor of 7½ h.p. 720 r.p.m., obtained when cast-steel pole shoes were counterbored, as indicated in Fig. 1.

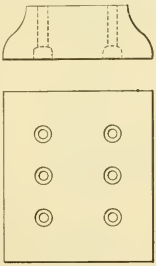
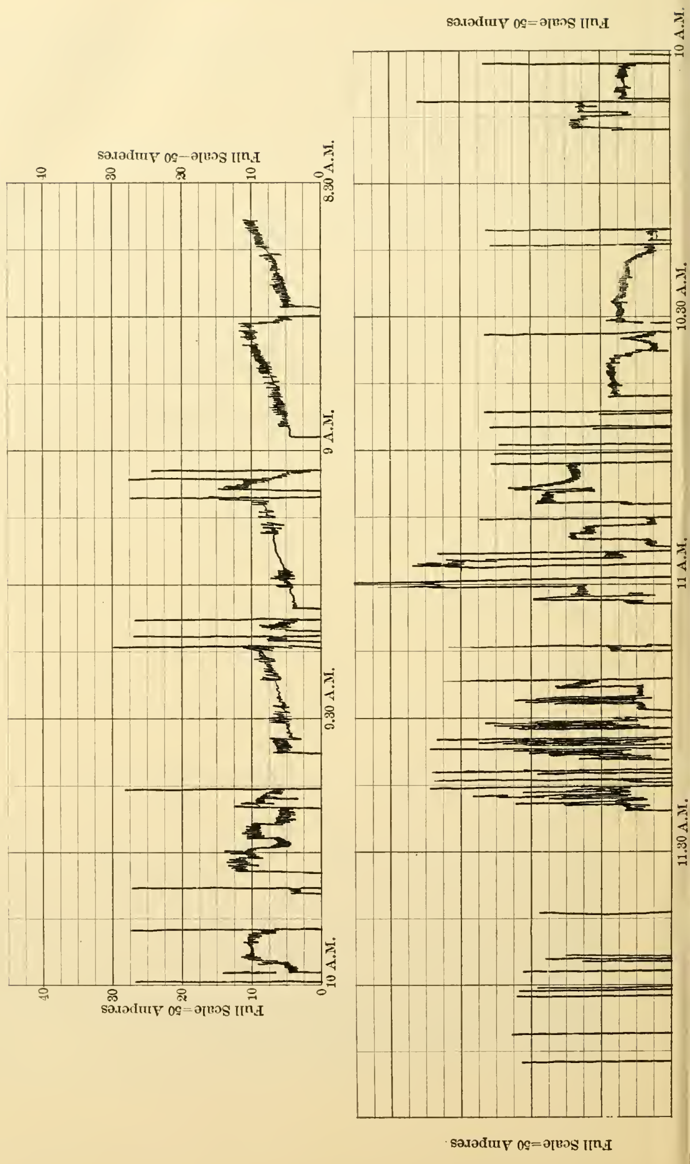


Fig. 1 Pole Shoe, Drilled and Counter Bored

5 The record (not here printed) shows 7½ min. required to counterbore each of the six holes per pole shoe. The sum of these is about 44 min. The total time for adjusting the drill is given under column headed "Adjust," and was from 15 to 24 min. for each pole shoe. The time consumed in removing and replacing the shoes in the clamps is tabulated under column headed "Change." This ranged from 7½ min. to 10 min. The time to complete counterboring each pole shoe varied from 70 to 75 min. The actual cutting or drilling time was from 57 to 64% of the total time to complete a pole shoe. From 10 to 14% of the time was consumed in changing the shoes, and from 22 to 33% was consumed in adjusting the drill. The average power consumed was 2.8 kw., making a load factor of about 37%.


Full Scale—50 Amperes
0
10
20
30
40
8.30 A.M.
9 A.M.
9.30 A.M.
10 A.M.
Full Scale=50 Amperes
10.30 A.M.
11 A.M.
11.30 A.M.

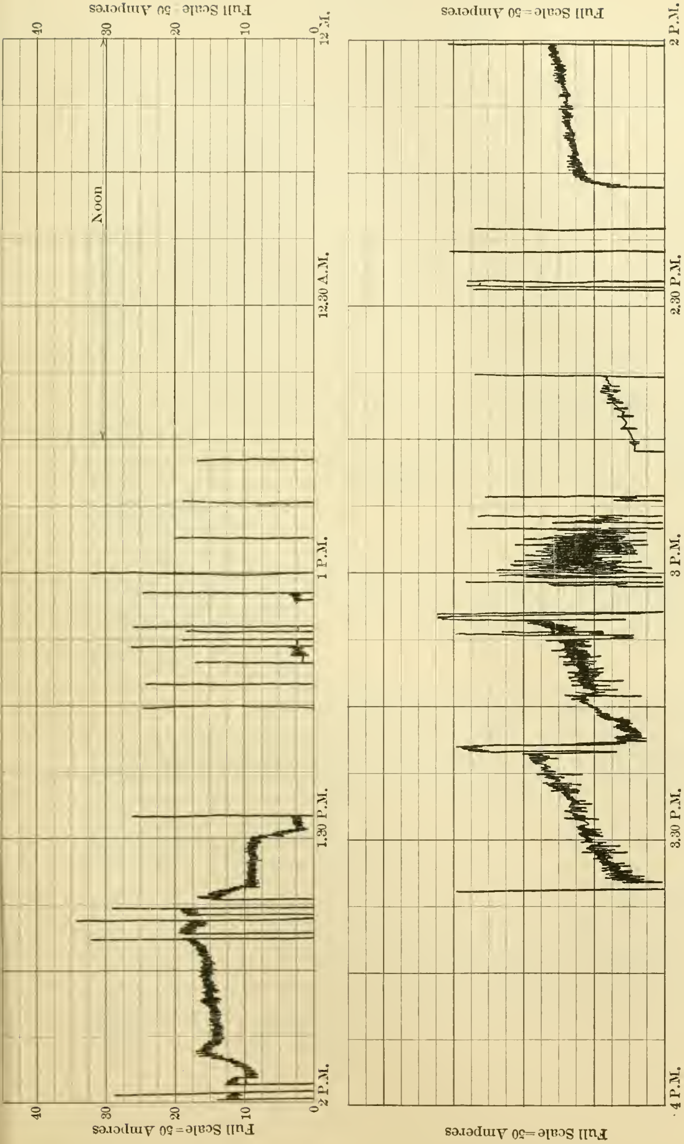


FIG. 2 COMPLETE METER RECORD FOR ONE DAY FROM 72-IN. BORING MILL

TABLE 2 ANALYSIS OF A COUNTERBORING OPERATION

	Number of Hole						Total Time To Drill	Adjustment	Change	Complete
	1	2	3	4	5	6				
Min.	7.3	7.5	7.4	7.5	7.4	7.5	44.6	19.6	8.2	72.4
% of Total							61.5	27.2	11.3	100
Min.	7.1	7.4	7.3	7.4	7.4	7.4	44	17.7	8.4	70.1
% of Total							62.8	25.2	12.0	100
Min	7.5	7.5	7.5	7.3	7.4	7.5	44.7	15.5	9.9	70.1
% of Total							64	22	14	100
Min	7.3	7.1	6.8	7.0	7.1	7.5	42.8	24.2	7.5	74.5
% of Total							57.5	32.5	10	100

No. load of drill, 1.75 kw. Power to drill, 1.75 kw. Average running load, 2.8 kw.

TABLE 3 ANALYSIS OF DRILLING AND TAPPING OPERATION

Set up equals 56 Min.

Pole No.	Operation	Time Required, Minutes Hole No.						Total Time Required			
		1	2	3	4	5	6	To Drill	To Adjust Drill	To Change Drill	Complete
1	$1\frac{9}{16}$-in. drill	1.1	1.3	1.1	1.3	1.3	1.3	7.4	5.6	....	13
	$1\frac{9}{32}$-in. drill	4.5	4.2	4.4	4.3	4.2	6.6	28.2	6.0	8.3	42.5
	$1\frac{5}{16}$-in. tap	0.9	0.6	0.7	0.7	0.5	0.8	4.2	13.2	6.6	24
							Total min.	39.8	24.8	14.9	79.5
							% of total	50	31.2	18.8	100
Turn Over = 26.2 min. delay for drawing = 31.4 min.; other delay = 57											
2	$1\frac{9}{16}$-in. drill	1.4	1.3	1.3	1.1	1.2	1.1	7.4	6.3	....	.....
	$1\frac{9}{32}$-in. drill	5.0	4.8	4.8	4.6	4.9	4.6	28.7	8.2	....	.....
	$1\frac{5}{16}$-in. tap	0.9	1.1	1.1	1.1	1.1	1.1	6.4	30.5	12.5	100
							Total, min.	42.5	45.0	12.5	100
							% of total	42.5	45.0	12.5	100
Turn Over = 21.2											
3	$1\frac{9}{16}$-in. drill	1.7.	1.3	1.5	1.2	1.5	1.2	8.4	4.4	....	.....
	$1\frac{9}{32}$-in. drill	4.9	5.1	5.6	5.4	5.4	4 7	31.1	......	3.8	.....
	$1\frac{5}{16}$-in. tap	0.6	0.8	0.6	0.8	0.8	0.6	4.2	14.3	8.4	.....
							Total min.	34.7	18.7	12.2	65.6
							% of total	53	28	19	100

DRILLING AND TAPPING

6 Table 3 is from a record made while an 8-pole revolving field was drilled and tapped for fitting pole shoes. To place the job in position required 56 min., owing to lack of prompt crane service. No lining up was required; the work was simply set upon the bed plate of the radial drill.

7 The total time consumed in adjusting the drill to proper position per pole was 5.6 min. The $1\frac{9}{16}$-in. holes were first drilled $\frac{3}{8}$-in. deep, requiring about 1.2 min. each, a total time for drilling the six holes of 7.4 min. The $1\frac{9}{16}$-in. drill was then removed and replaced by a $1\frac{9}{32}$-in. drill, requiring about 8 min. To drill each $1\frac{9}{32}$-in. hole $2\frac{1}{2}$ in. deep took about $4\frac{1}{2}$ min., or 28 min. for the six holes. Adjustments of the drill took 6 min., making a total time of $42\frac{1}{2}$ min. to complete drilling the six $1\frac{9}{32}$-in. holes. The drill was then removed and a $\frac{5}{16}$-in. tap substituted, this change requiring 6.5 min. To tap each hole took from 0.6 to 0.9 min., making a total of 4.2 min. for the six holes. The time taken for adjustments was 13.2 min., making a total of 24 min. for the tapping operation. The actual cutting time for tapping was $17\frac{1}{2}$% of the total time. The total cutting time per pole, including one tapping and two drilling operations, was 50% of the total completing time, 31.2% of the time being consumed in adjusting, and 18.8 % in changing drills for taps. About 20 to 30 min. were consumed in waiting for a crane to turn over the job in order to drill the next pole piece. The time required to complete the job can be analyzed as follows:

Set up and wait for crane	56 min.
Complete poles	560 min.
Turn over (crane service)	240 min.
Total	856 min., or 14 hr. 16 min.
Total cutting time	320 min., or 5 hr. 20 min.
Time factor	38%

RECORDS FROM 5-FT. RADIAL DRILL

8 The following results were obtained by taking records on a 5-ft. radial drill driven by a $7\frac{1}{2}$-h.p. adjustable-speed motor, with rated speeds ranging from 400 to 1600 r.p.m., while drilling a series of holes in a large steel casting. Out of $11\frac{1}{2}$ hr., 4 hr. 42 min. were consumed in actual drilling, the other 6 hr. 48 min. being required to make adjustments. In this case, the time factor was 41%. The average running load while drilling was 1.5 kw., making an average daily load of 0.7 kw., or a load factor of 10%.

9 While drilling a series of 22 holes, 67.5% of the time was consumed in actual drilling, the remaining 32.5% being consumed in moving the drill from one position to the next. In another case where holes were to be drilled and tapped, 74.5% of the time was consumed in actual drilling; while in tapping the holes, the machine was in use 44% of the time, the remainder being consumed in making adjustments. Records taken while a series of small jobs were drilled show that the time factor was as low as 20%, much time being lost in obtaining drawings and auxiliary materials.

PORTABLE MILLING MACHINE

10 On a portable milling machine driven by an induction motor of 3 h.p., 720 r.p.m., while milling slots and dovetails in an iron casting, the average running load was 1.5 kw. to 2 kw., giving a load factor of from 50 to 67%. The time factor was 54%. 24% of the total time was required to make adjustments of the cutting tool; the remaining 22% was required to set up the job, that is, to place the portable machine in a central position upon a table inside the circular casting where the machine could be completely revolved and clear the inside of the frame.

PORTABLE SLOTTER

11 On a portable slotter driven by a 10-h.p., 720-r.p.m. motor while cutting slots in a cast-iron frame, the arm carrying the cutting tool is moved up and down by reduction gearing and a rack. The cut is taken on the up-stroke. The record (not printed) shows that the peak load occurs just before the cut is taken, i.e., when the arm is reversed for the upward motion; the minimum load occurs on the downward stroke. The record also shows a variation in the amount of power required to produce the cut. This variation is due to irregularities in the feeding mechanism on the machine tested, a ratchet which had become worn. The time factor was 50% and the load factor 12%.

COMPARISON OF MILLING AND SLOTTING

12 From the results obtained an interesting comparison can be drawn between the time required to cut slots with a miller and with a slotter, as shown in the following table:

	Size of Slots Inches	Cutting Time Minutes	Minutes to Cut 1 In.
Miller	$7\frac{1}{8} \times \frac{5}{8} \times 12\frac{1}{2}$	11.8	0.95
Slotter	$7\frac{1}{8} \times \frac{5}{8} \times 15\frac{3}{4}$	8.4	0.53

13 The results show that the actual cutting time per inch of the slotter is but 56 % of the time of the miller; both were removimg exactly the same amount of material. The curves also show that the intervals required for adjustment of the positions of the tools from one slot to another averaged 6.1 min. on the miller and 3.1 min. on the slotter, an advantage of 50% again in favor of the slotter. The time to set up the work must be included in order to determine the relative advantage of one machine over the other. The setting-up time was found to depend more upon the work than upon the tool, and neither tool had an advantage. Two hours were required to set up the job on each tool. The results may then be summarized by comparing the operations of the machines in cutting two similar jobs of 12 slots 10 in. long:

	Setting up Time	Adjustments	Cutting Slots	Total
Miller	2 hr.	1 hr. 12 min.	1 hr. 44 min.	4 hr. 56 min.
Slotter	2 hr.	0 hr. 36 min.	1 hr. 04 min.	3 hr. 40 min.

14 This shows that the total time required by the slotter was but 74% of that required by the miller; a saving of 1 hr. 16 min. on every such job.

POWER REQUIRED TO OPERATE PLANERS

15 Table 4 contains a summary of results to determine the power required to operate various motor-driven planers. The average time factor in ordinary planing operations is about 50 to 60%.

CURVES FROM MACHINES IN A STEEL TUBE MILL

16 Fig. 3 shows a curve taken from a motor operating welding rolls while lap welding 5-in. tubes. The rolls were driven by a 150-h.p. induction motor.

TABLE 4 ANALYSIS OF POWER REQUIRED TO OPERATE PLANERS

Size Planer	H. P. of Motor	Reversal *a* Kw.	Reversal *a* % Full Load	Reversal *b* Kw.	Reversal *b* % Full Load	Cutting Stroke Kw.	Cutting Stroke % Full Load	Reverse Stroke Kw.	Reverse Stroke % Full Load	No Load	Average Running Load Kw.	Average Running Load % Full Load	Load Factor at 50% Time Factor
56 in. x 12 ft.	15	8.5	56	6.5	43	2.5–5	17–34	3	20	2	4–5	30	15
7 ft. x 12 ft.	15	6	40	3	20	1–2	7–14	0.75	5	0.6	4	25	12.5
14 ft. x 20 ft.	30	34	113	30	110	6–10	20–34	8	27	5.5	11	35	17
10 ft. x 20 ft.	50	22	45	16	30	12–16	25–32	7	14	4.5	16	30	15
14 ft. x 30 ft.	40	40	115	24	60	10–16	25–40	10	25	5	15	36	18

Reversal *a*, from cutting to return stroke.
Reversal *b*, from return to cutting stroke.

To reduce the peak load thrown on the motor, the rolls were equipped with a 5-ft. diameter, 5000-lb. fly wheel. This record is interesting, in that it shows that a friction load of 12 kw. was required about 91% of the time, under which condition of operation the motor, on account of its light load, was operating at a power factor of about 30%, which is an undesirable condition for the power plant.

17 The duration of peak load is in each instance about eight seconds, which amounts to only about 9% of the total cycle of operation. During this period the input to the motor was from 128 to 160 kw. A study of the records shows that a smaller motor should be installed. The motor should be designed with a larger slip, or drop in speed between no load and full load, so that with a some-

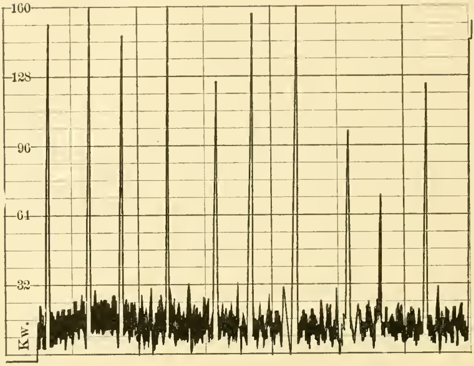


FIG. 3 RECORD FROM WELDING ROLLS EQUIPPED WITH FLYWHEEL

what larger flywheel, when the load is steadily thrown on the motor, it would slow down, allowing the fly wheel to give forth energy and in this way moving out or lowering the peaks for instantaneous demand for current from the line. With a smaller motor the power factor would be increased, the efficiency improved, and the load factor also improved. At the time the tests were made a meter was used, having a paper speed of 24 in. per hr. The record shows that tubes were rolled at the rate of 40 per hour.

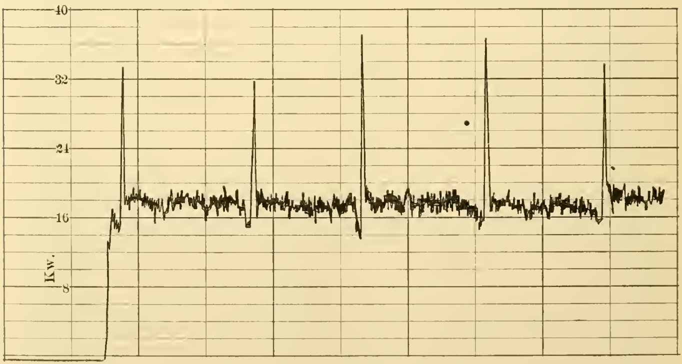


FIG. 4 RECORD FROM HOT-ROLL SCARFER

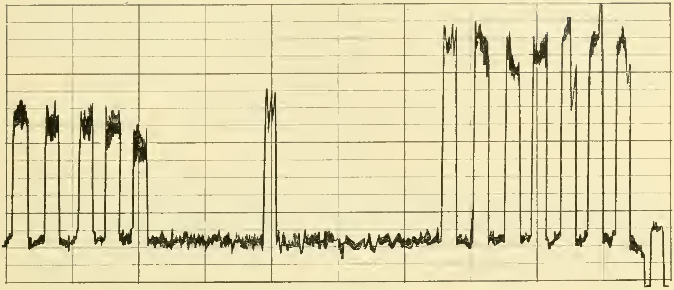


Fig. 5 Record from Shear Scarfer

18 The curve represented by Fig. 4 was taken from a 75-h.p. motor, operating a hot-roll scarfer, scarfing sheets for 12-in. lap-welded tubes. It shows that the friction load of 18 kw. is practically constant for about 90 % of the time, and that the maximum or peak load of about 34 kw. occurred for about 4% of the total time. At the time these records were taken the meter was operating at a speed of 24 in. per hr., and the rolls turning out 10 and 15 tubes per hour. The difference in peak load is due to the fact that an increase in width of the metal causes a slight increase in power. Undoubtedly a 50-h.p. motor would have been satisfactory for this work with much more economy than the installed motor.

19 The curve represented by Fig. 5 is a record showing the operating conditions of a 50-h.p. induction motor driving a shear scarfer. On this curve the

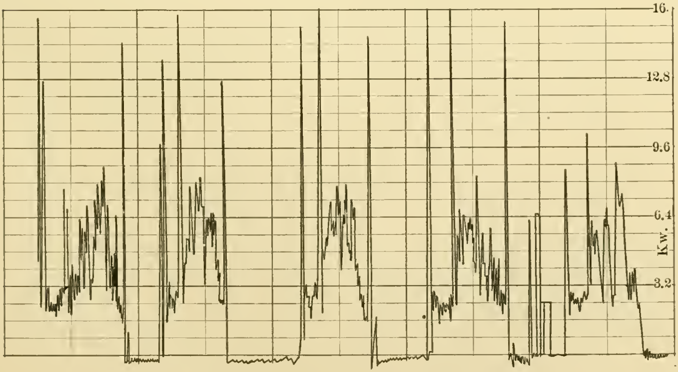


Fig. 6 Record from Pipe Cutting-off Machine

friction load was shown at about 2.3 kw., of a duration of 55% of the time. The peak loads require from 10 to 13 kw. for the balance, or 45% of the time. As the duration of the peak is only about 34 seconds, a smaller motor of about 25 h.p. would be of sufficient capacity to do the work. In this instance, as in the others, a meter having a 24-in. movement of the record was used.

PIPE CUTTING-OFF MACHINE

20 The record shown in Fig. 5 was taken from a 5-h.p. motor operating a pipe cutting-off machine, cutting 18-in. tubes at an average cutting speed of about 38 ft. per min. It will be noted that about 16 kw. were required for starting, while the average load during cutting was about 6 kw. The motor was reversed for the reaming operation, and the peak was very large, going off the scale. To start the machine the motor was again reversed, such manipulation causing very severe overloads on the motor and the gearing to the machine. For a reversing operation of this nature an induction motor having a large slip would be desirable, or a slip-ring type of motor, thus reducing the demand upon the line. A direct-current motor, if used, should be supplied with very heavy compound winding.

APPENDIX NO. 2. POWER REQUIRED TO REMOVE METAL

1 The power required to remove metal depends upon the nature of the cutting tool and the amount of metal removed per minute. Cutting tools may be divided into three general classes: (*a*) lathe tool type; (*b*) drills; (*c*) milling cutters.

LATHE TOOL TYPE

2 The lathe tool is used on lathes, boring mills, planers, shapers and slotters. Tests show that the power required by a tool of this kind when removing metal depends upon the cutting angle of the tool and the number of cubic inches of metal removed per minute. From observation and data

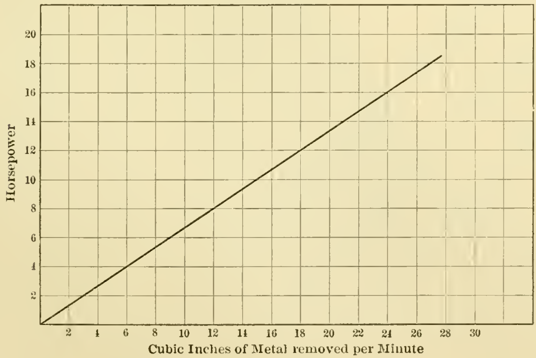


Fig. 1 Relation between Horsepower and Cubic Inches Metal Removed; Mild Steel, 0.40% Carbon

obtained by means of the graphic recording meter, and the use of tools having a cutting angle of about 75 deg. to 80 deg. the curve shown in Fig.1 was obtained. The results were independent of the cutting speed, feed and depth of cut, and show that a definite relation exists between the horsepower required to remove metal and the number of cubic inches removed per minute. The cubic inches of metal removed per minute were found to be as follows:

(*a*) area of cut(sq. in.) × cutting speed (ft. per min.) × 12

(*b*) area of cut(sq. in.) = depth of cut(in.) × feed (in. per revolution)

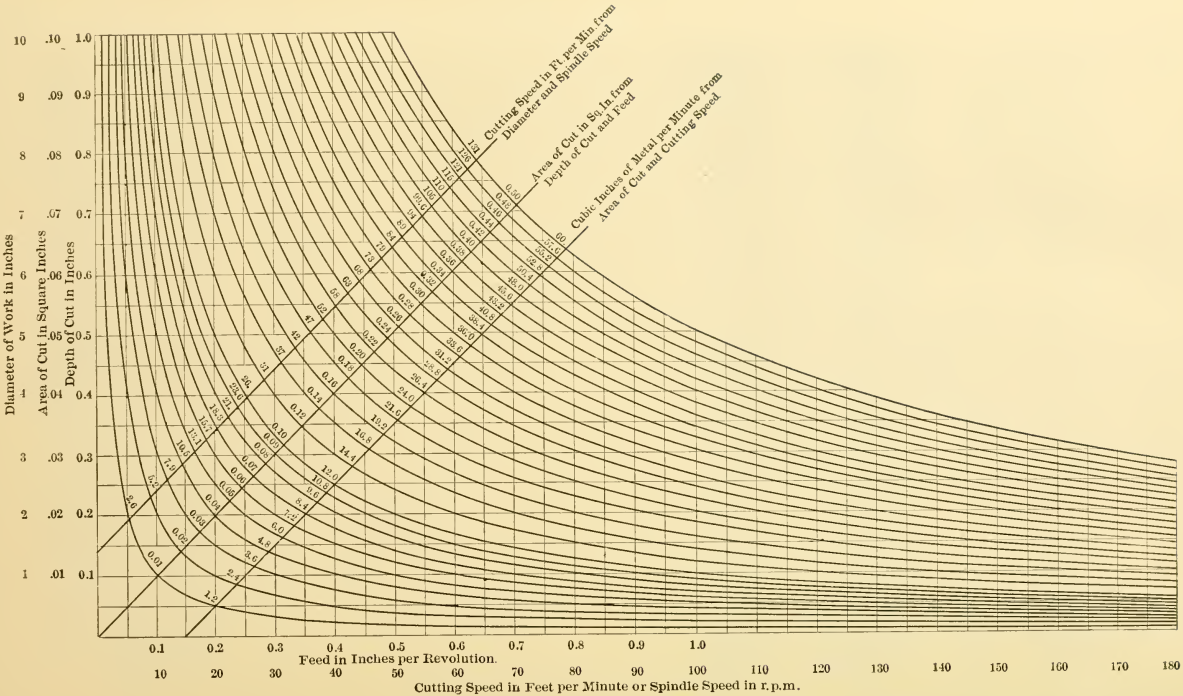


PLATE 1 MACHINE TOOL CALCULATOR FOR LATHES, PLANERS, SHAPERS, SLOTTERS AND BORING MILLS

DIRECTIONS FOR USING PLATE 1

a To find cutting speed: From intersection of horizontal line corresponding to diameter and vertical line corresponding to spindle speed, follow nearest curve and use value found in oblique line of figures marked cutting speed.

b To find area of cut: From intersection of horizontal line corresponding to depth of cut and vertical line corresponding to feed, follow nearest curve and use value found in oblique line of figures marked area of cut.

c To find cubic inches of metal removed per minute: From intersection of horizontal line corresponding to area of cut and vertical line corresponding to cutting speed follow nearest curve and use value found in oblique line of figures marked cubic inches of metal removed per minute.

To use curve, knowing diameter of work, spindle speed, depth of cut and feed, find cutting speed from (*a*) area of cut from (*b*) and cubic inches of metal removed per minute from (*c*).

3 The horsepower required to remove metal with the tools ordinarily employed can be expressed by:

$$\text{h. p.} = \text{a constant} \times \text{cu. in. removed per min.}$$

The constant varies with the kind of metal removed.

4 In order to estimate the amount of power required to remove a given amount of metal per minute the graphic method shown in Plate 1 has been designed. This diagram is a multiplication table; those familiar with analytical geometry will recognize the equilateral hyperbola whose equation, referred to its asymptotes, is xy = constant.

5 To determine the cutting speed the usual procedure is as follows:

$$\text{cutting speed (ft. per min.)} = \frac{\pi \times \text{diameter} \times \text{r.p.m.}}{12}$$
$$= \text{constant} \times \text{diameter} \times \text{r.p.m.}$$

In the diagram each hyperbola corresponds to a given cutting speed. The coördinates of all diameters and spindle speeds producing the same speed intersect on the same hyperbola. The cutting speed corresponding to any diameter, rotation at any number of r.p.m., is found indicated on the hyperbola passing through the intersection of the coördinates corresponding to the given values of diameter and r.p.m.

6 In a similiar manner an area corresponding to any depth of cut in inches and feed in inches is obtained, and also the cubic inches of metal removed per minute can be determined from the area of cut and the cutting speed. The directions for using the diagram are given in connection with it.

7 With the cutting tools ordinarily employed the following values have been found by tests to exist for the horsepower required to remove 1 cu. in. of the following metals, per min.:

Brass and similar alloys	0.2 to 0.3
Cast iron	0.3. to 0.5
Wrought iron	0.6
Mild steel (0.30%–0.40% carbon)	0.6
Hard steel (0.50% carbon)	1.00 to 1.25
Very hard tire steel	1.50

8 It must be remembered that these constants represent general average conditions; considerable variation may occur where special cutting tools are used and special grades of metal are encountered.

LATHES

9 The following examples will explain the application of the diagram, Plate 1, to lathe work.

Example:	Diameter of work	= 5.5 in.
	Spindle speed	=45 r.p.m.
	Depth of cut	=0.45 in.
	Feed per revolution	=0.06 in.

10 Find the intersection of the horizontal line through 5.5 in. diameter of work, and the vertical line through 45 r. p. m. spindle speed. The curves pas-

sing nearest this intersection correspond to a cutting speed of 63 and 68 ft. per min., indicating by interpolation a cutting speed in this case of 65 ft. per min. The area of cut, with depth of cut 0.45 in. and feed 0.06 in. is 0.027 sq in. The cubic inches of metal removed per minute, corresponding to an area of cut 0.027 sq. in. and a cutting speed of 65 ft. per min., is determined by finding the intersection of the horizontal line passing through 0.027 sq. in. area of cut and 65 ft. per min. This intersection is between the curves corresponding to 19.2 and 21.6 cu. in., showing that about 20 cu. in. of metal are removed per min. If the metal removed is wrought iron, the horsepower required is $0.6 \times 20 = 12$ h.p. If 0.50% carbon steel is turned, $1.00 \times 20 = 20$ h.p., is required. Brass would require $0.25 \times 20 = 5$ h.p.

BORING MILL

Example:	Diameter of work	=45 in.
	Speed of table	= 4.5 r.p.m.
	Depth of cut	= 0.25 in.
	Feed	=0.10 in. per revolution

11 The diameter of work goes only to 10 in. in the vertical column of the diagram. These may be multiplied by 10, and if used with the spindle speeds as they stand, the results in the oblique column of cutting speeds must be multiplied by 10. In case of large diameters the spindle or table speeds are usually low. The simplest way to use the diagram in these cases is to interchange *diameter of work and spindle speed*, i. e., assume that the diameter of the work is 10, 20, 30, etc., in the horizontal column, and the table speed under 1, 2, 3, etc., in the vertical column. In the problem under consideration the cutting speed is as follows:

12 The intersection of the horizontal line through 4.5 and the vertical line through 45 correspond to a cutting speed of 52 ft. per min. The area of cut is 0.025 sq. in. The intersection of the horizontal line through 0.025 sq. in. area of cut, and the vertical line through 52 ft. per min. cutting speed lies between curves representing 14.4 and 16.8 cu. in., indicating that 15 cu. in. are removed per min. If cast iron of a soft quality is removed the power required for cutting will be $15 \times 0.3 = 4.5$ h. p. If the cast iron is of hard quality, $0.5 \times 15 = 7.5$ h. p., will be required.

SHAPER OR PLANER

Example:	Depth of cut	= 0.75 in.
	Feed per stroke	= $\frac{1}{16}$ in.
	Cutting speed	= 45 ft. per min. (from characteristic of planer or shaper)

Area of cut $0.75 \times \frac{1}{16} = 0.046$ sq. in.

13 The cubic inches of metal removed per minute, corresponding to an area of cut of 0.046 sq. in., and a cutting speed of 45 ft. per min., is 24. The power required for cutting in the machine a hard grade of cast iron will under these conditions be $24 \times 0.5 = 12$ h. p.

14 In a planer the power required for reversing is usually considerably more than that required to cut metal, depending upon the design of the reversing

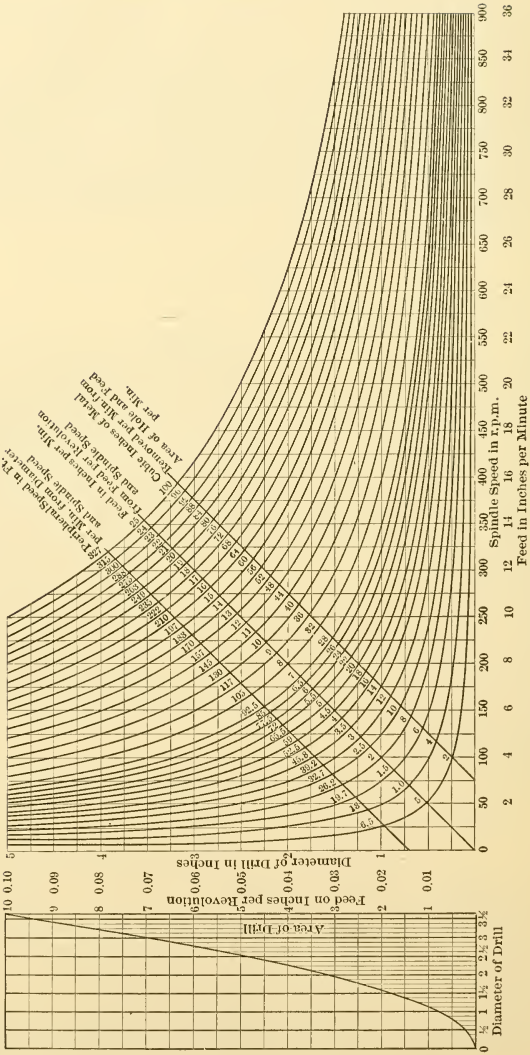


PLATE 2 MACHINE TOOL CALCULATOR FOR DRILLS

DIRECTIONS FOR USING PLATE 2

a To find cutting speed: From intersection of horizontal line corresponding to diameter of drill and vertical line corresponding to spindle speed, follow nearest curve and use value found in oblique line of figures marked cutting speed.

b To find feed in inches per minute from feed per revolution and spindle speed: From intersection of horizontal line corresponding to feed in inches per revolution and vertical line corresponding to spindle speed follow nearest curve and use value found in oblique line of figures marked feed in inches per minute.

c To find area of drill from diameter of drill use curve on left side of figure: Find intersection of vertical line corresponding to diameter of drill with the curve follow the horizontal line passing through this intersection and obtain area under area of drill in vertical column.

d To find cubic inches of metal removed per minute: From intersection of horizontal line corresponding to area of drill and vertical line corresponding to feed per minute follow nearest curve and use value found in oblique line of figures marked cubic inches of metal removed per minute.

Knowing diameter of drill, spindle speed and feed per revolution, find cutting speed from (*a*), and cu. in. metal removed per minute from (*b*), (*c*), and (*d*).

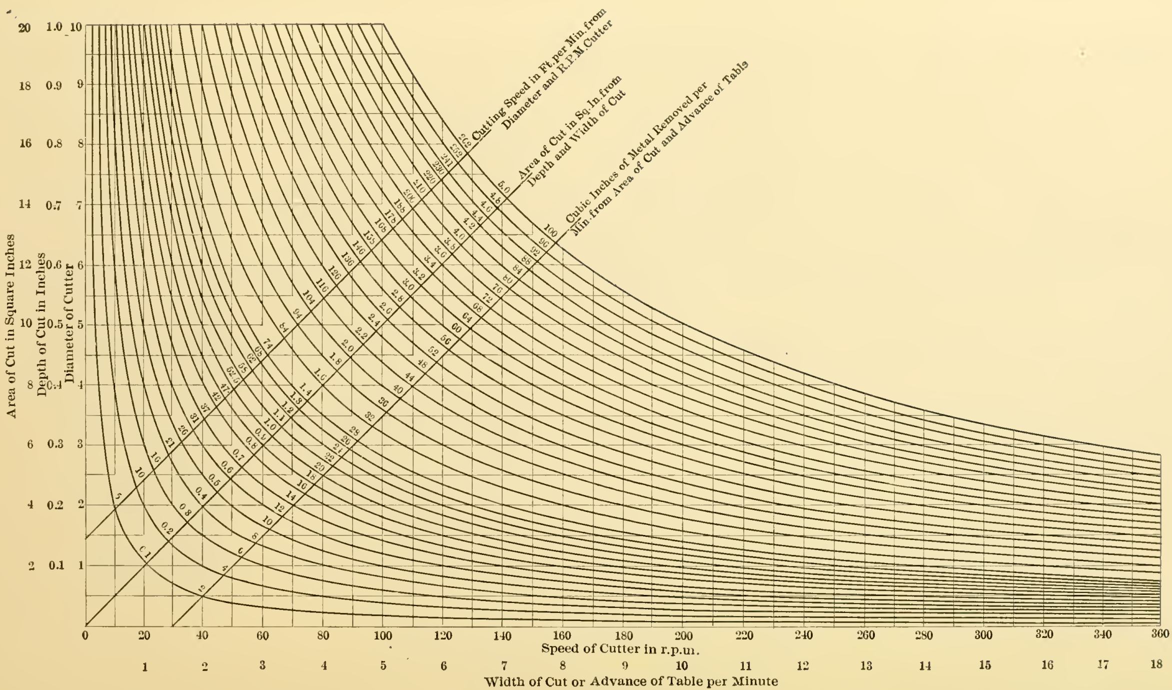


PLATE 3 MACHINE TOOL CALCULATOR FOR MILLING MACHINES

DIRECTIONS FOR USING PLATE 3

a To find cutting speed: From intersection of horizontal line corresponding to diameter and vertical line corresponding to spindle speed of cutter, follow nearest curve and use value found in oblique line of figures marked cutting speed.

b To find area of cut: From intersection of horizontal line corresponding to depth of cut and vertical line corresponding to width of cut, follow nearest curve and use value found in oblique line of figures marked area of cut.

c To find cubic inches of metal removed per minute: From intersection of horizontal line corresponding to area of cut and vertical line corresponding to advance of table per minute, follow nearest curve and use value found in oblique line of figures marked cubic inches of metal removed per minute.

To use curve, knowing the diameter of cutter, spindle speed, depth of cut, width of cut, and advance of table per minute, find cutting speed from (*a*), area of cut from (*b*), cubic inches metal removed per minute from (*c*).

mechanism, the flywheel effect and the speed characteristic of the motor. In a shaper the power required to reverse is not very great, and is usually less than the power required for cutting.

SLOTTER

15 In most cases the cutting tool is fed inwardly on this type of machine; the following example shows how the diagram is used to determine the rate of removing metal. With other methods of feeding the tool the diagram is used in the same way as in the case of a planer or a shaper.

Example:	Width of tool and cut	= 0.5
	Feed per stroke	= 0.06
	Cutting speed	= 35 ft. per min.
	Area of cut 0.5 x 0.06	= 0.03 sq. in.

16 The cubic inches of metal removed per minute from the intersection of the horizontal and vertical line through 0.03 sq. in. and 35 ft. per min. are 13. In the case of mild steel the horsepower required would be 13 x 0.6 = 7.8 h. p.

DRILLS

17 The power required in drilling operations can also be expressed as a constant times the cubic inches of metal removed per minute. The conditions are, however, more complicated than in the lathe tool, since the friction of the drill and the chips on the sides of the hole increase the power requirement as the drill enters the metal. This is especially true when cast iron is drilled, as chips have a jamming action. The variable cutting speed at the cutting edge of the drill, from zero at the center to the peripheral speed of the drill, also causes a jamming action and tends to increase the power per cubic inch per minute over that required to remove the same amount of metal by means of the lathe tool type. With drills generally employed, the value per horse power per cubic inch of metal removed per minute. is about double that required by ordinary lathe tools.

18 Plate 2 is a diagram with full instructions for determining the cubic inches of metal removed with drills. The constants for determining the power required are about double those for lathe tools.

Example:	Size of drill	= 2 in. diameter
	Feed per minute	= 2.5 in.
	Speed of drill	=150 r.p.m.
	Metal drilled: cast iron.	

19 The peripheral or maximum cutting speed of the drill is found as follows (Rule *a*, Plate 2): The horizontal line corresponding to a diameter of 2 in. intersects the vertical line corresponding to 150 r.p.m. on the curve corresponding to a cutting speed of 77.5 ft. per min. The area of the 2 in. drill (rule *c*) is 3 sq. in. This area at a feed of 2.5 in. per min. corresponds to removing 7 cu. in. per min. (rule *d*). For cast iron the horsepower per cu. in. per min. is about 0.8, twice that for lathe tools, hence the power required to drive the drill in this case is $0.8 \times 7 = 5.6$ h.p., which agrees closely with an actual test. For

mild steel the power required is $1.2 \times 7 = 8.4$ h.p. In drilling a hole of this size the friction of the chips does not increase the power materially as the depth of the hole increases, since there is sufficient space for the drill to free itself of chips.

MILLING CUTTERS

20 Plate 3 is a diagram with full instructions for determining the amount of metal removed per minute by a milling machine.

Example:	Width of cut	= 8 in.
	Depth of cut	= 0.2 in.
	Advance of table per min.	= 5 in.
	Area of cut is 8×0.2	= 0.16 sq. in.

21 To find the cubic inches of metal removed per minute, find on the diagram the intersection of the horizontal line through 0.16 sq. in., and a vertical line corresponding to a table advance of 5 in. per min. The curve passing through this intersection corresponds to a rate of cutting of 16 cu. in. of metal per min. For machinery steel or mild steel, the power required by a horizontal milling machine of this type is about 1.6 per cu. in. per min, making the total requirement $1.6 \times 16 = 25.6$ h.p. A vertical miller requires about 1 h.p. per cu. in. per min., or 16 h.p. under the foregoing conditions.

22 The power required by milling cutters varies according to their construction, and care should be employed to determine the proper constant for each class of cutters. By means of tests made with the graphic meter on motor-driven tools the proper constant can easily be determined in any given case.

APPENDIX NO. 3. SIZES OF MOTORS RECOMMENDED TO DRIVE MACHINE TOOLS

The accompanying tables contain the sizes and speeds of motors usually employed with the average duty indicated for machine tools. The constant speed motors are selected with a view to utilizing speeds as near as possible to those obtainable with 60-cycle induction motors. By this means the same gear ratios can be employed with either direct current motors or 60 cycle induction motors.

2 The average load factor for motors driving lathes is from 10 to 25 %. On some special machines, as driving wheel and car wheel lathes, the cuts are all heavy, which increases the average load factor to from 30 to 40%.

3 For extension boring mills, 5 h.p. motors are used to move the housings on from 10 ft. to 16 ft. mills, 7½ h.p. for from 14 ft. to 20 ft. mills and 10 h.p. for from 16 ft. to 24 ft. mills. The load factor of the driving motor on boring mills averages fom 10 to 25 %.

4 The load factor of motor-driven drills is about 40%, when the larger drills applicable thereto are used. If the smaller drills are used the load factor averages 25% and lower.

5 For the average milling operations the load factor averages from 10 to 25 %. On slab milling machines where large quantities of metal are renewed it will average from 30 to 40%.

6 The work on this class of machinery is usually light and much time is required in making adjustments. Hence the load factor is rarely higher than 20%.

7 On planers the load factor averages between 15 and 20%. The motor must be large enough to reverse the bed quickly, yet this peak load occurs for such short intervals that it does not increase the average load per cycle very much.

8 The work done on shapers is of a varying character. With light work the load factor will not exceed from 15 to 20%; with heavy work, the load factor will be as high as 40%.

9 The conditions encountered on slotters are similar to those on shapers.

TABLE 1 SIZES AND SPEEDS OF MOTORS ON LATHES

ENGINE LATHES

Adjustable speed, ratio 1 : 3.

Swing In.	Light Duty			Medium Duty			Heavy Duty		
	h.p.	Adjst. Speed	Const. Speed r.p.m.	h.p.	Adjst. Speed	Const. Speed r.p.m.	h.p.	Adjst. Speed	Const. Speed r.p.m.
14	2	Ratio	1800	3	Ratio	1800	5	Ratio	1200
16	3	1 : 3	1800	5	1 : 3	1200	5	1 : 3	1200
18–20	3		1800	5		1200	7 : 5		1200
22–24	5		1200	7 : 5		1200	10		1200
27–30	7½		1200	10		1200	15		1200
36–48	7½		1200	10		1200	20		900

SPECIAL LATHES

Type	h.p.	Adjustable Speed
Car wheel 48 in.	20	1 : 3
Double axle, moderate duty	15	1 : 3
Heavy duty	25	1 : 3

DRIVING WHEEL LATHES

Size, in.	h.p.	Adjustable speed
51	15	Ratio 1 : 3
60–69	20	
79	25	1200 r.p.m.
84	25	
90	30	
100	50 5 tail stock	

TABLE 2 SIZES AND SPEEDS OF MOTORS

Vertical Boring Mills

Size, in.	h.p.	Adjustable Speed	Constant Speed
24–30 in.	5	Ratio 1 : 3	1200
36–42 in.	7½		1200
60–90 in.	10 5–rail		1200
100 in.	15 5 –rail		1200
10 ft.	20 7½–rail		900
12 ft.	20 7½–rail		900
14 ft.	25 7½–rail		900
16 ft.	30 10–rail		900

TABLE 3 SIZES AND SPEEDS OF MOTORS ON DRILLS

Radial Drills

Size, ft.	h.p.	Adjustable speed	Constant Speed
4	3	Ratio 1 : 3	1800
5	5		1200
6	5		1200
10	7½		1200

Upright Drills

Size, in.	h.p.	Adjustable Speed	Constant Speed r.p.m.
Friction	½	Ratio 1 : 3	1800
15	½		1800
20–26	1		1800 1200
28–34	2		1800 1200
42–50	3		1800 1200

Multiple-Spindle Drills

Size, in.	h.p.	Adjustable Speed	Constant Speed
4–2	7½	Ratio 1 : 3	1200
6–2	10		1200
8–2	10		1200

TABLE 4 SIZES AND SPEEDS OF MOTORS ON MILLING MACHINES

HORIZONTAL—PLAIN OR UNIVERSAL

Table Feed In.	Cross Feed In.	Vertical Feed In.	h.p. Mod. Heavy	Adjustable Speed	Constant Speed r.p.m.
24	8	18	3	Ratio 1 : 3	1800
30	10	18	5– 7½		1200
36	12	20	7½–10		1200
50	12	20	10–15		....

VERTICAL MILLING MACHINES

Table Diameter in.	Spindle Diameter in.	h.p.	Adjustable Speed	Constant Speed r.p.m.
28	4	5	Ratio 1 : 3	1200
32	4	7½		1200
40	4½	10		1200
54	5	15		1200
70	6	20		900

SLAB MILLING MACHINES

Width of Table, in.	h.p.	Adjustable Speed	Constant Speed r.p.m.
24–30	10	Ratio 1 : 3	1200
36	15		1200
60	25		900
36 heavy	25		900
42 heavy	50		900

TABLE 5 SIZES AND SPEEDS OF MOTORS

HORIZONTAL BORING, DRILLING AND MILLING MACHINES

Spindle, in.	h.p.	Adjustable Speed	Constant Speed r.p.m.
3½	3	Ratio 1 : 3	1800
4	5		1200
5	7½		1200
6	10		1200
7	15		1200

TABLE 6 SIZES AND SPEEDS OF MOTORS ON PLANERS

Medium Duty			Heavy Duty		
Size, in.	h.p.	Constant Speed r.p.m.	Size, in.	h.p.	Constant Speed r.p.m.
24 x 24	5	900	24 x 24	7½	900
30 x 30	7½	900	42 x 42	25	900
36 x 36	10	900	56 x 56	25	900
48 x 48	15	900	Frog and	30	900
56 x 56	15	900	Switch Forge	...	...
			12 x 10 ft.	60	720
			14 x 12 ft.	10 (rail)	...
				75	...
				12 (rail)	720

TABLE 7 SIZES AND SPEED OF MOTORS ON SHAPERS

Size In.	h. p.	Adjustable Speed	Constant Speed r. p. m.
14–20	3	Ratio 1:3	1800
24	5		1200
36	7½		1200

TABLE 8 SIZE AND SPEEDS OF MOTORS ON CRANK SLOTTERS

Light, Medium and Heavy

Size In.	h. p.	Medium	Adjustable Speed	Constant Speed r. p. m.
10	3	5	Ratio 1:3	1800
10–16	5	7½		1200
20	7½	10		1200
26–30	15	..		1200

Geared Slotters

24–60	20	....	1:3	900

TABLE 9 SIZES AND SPEEDS OF MOTORS ON COLD SAWS

Diameter In.	Thickness In.	h. p.	Adjustable Speed	Constant Speed r. p. m.
12	$\frac{5}{32}$	2	Ratio 1:3	1800
15	$\frac{5}{32}$	2		1800
18	$\frac{3}{16}$	3		1800
20	$\frac{3}{16}$	3		1800
24	$\frac{3}{16}$	5		1200
32	$\frac{3}{16}$	$7\frac{1}{2}$		1200
36	$\frac{3}{16}$	10		1200

TABLE 10 SIZES AND SPEEDS OF MOTORS ON GRINDERS

Size In.	h. p.		Constant Speed r. p. m.
	Medium	Heavy	
10x 50	5	$7\frac{1}{2}$	1200
10x 72	5	$7\frac{1}{2}$	1200
10x 96	5	$7\frac{1}{2}$	1200
10x120	5	$7\frac{1}{2}$	1200
14x 72	10	—	1200
18x120	10	15	1200
18x144	10	15	1200
18x168	10	15	1200
18x 96	10	15	1200
44-in. car wheel grinder		30	900

APPENDIX NO. 4. CONDITIONS WHEN EQUIPPING OLD MACHINES WITH MOTOR DRIVE

1 When changing over from lineshaft drive to individual motor drive the question arrises whether to equip the old lineshaft-driven machines with motors or to install new motor-driven machine tools. The old machines are not as strong in construction as new tools designed for motor drive, nor are they equipped with the latest devices by means of which the time required to make adjustments can be greatly reduced. Owing to weaker construction old machines cannot be made to remove metal as rapidly as machines built with this point in view. The old machines are also more or less worn and not as accurate as new machines. A concrete example will show a method of arriving at a decision between attaching a motor to an old machine and purchasing a complete new motor-driven equipment.

2 The case taken for consideration involves the modification or exchange of a 72-in. vertical belt-driven boring mill, so as to obtain a greater output at lower cost per unit of product. This mill, the original cost of which was $3200, has been in use five years. The hourly overhead operating charge has been determined at 91 cents. The machinist receives 35 cents an hour for 54 hours per week (2808 hr. per year). The total earnings for the year from this machine amount to $4200. The operating expenses for the year are as follows:

Overhead 0.91×2808 =	$2555.28
Wages 0.35×2808 =	982.80
Total	$3538.08
Net profit $4200 − $3538 =	$662.00

3 The depreciated value of this tool on a basis of 10% reduced balance is 66% of its first cost. If a motor is installed the investment appears as follows:

Value of tool 0.66×3200 =	$2112.00
Cost of motor, gears, controller, wiring, etc. =	550.00
Total investment	$2662.00

4 The hourly overhead charge of 91 cents includes interest and depreciation at 16 cents an hour; the overhead change exclusive of interest and depreciation will therefore be 75 cents an hour. The depreciation on the new investment for the remaining five years' life of the tool will be 20% per year, making the

charge for interest and depreciation 26%. The operating cost of the old tool with motor drive is therefore,

Overhead (exclusive of interest and depreciation) $0.75 × 2808	= $2106.00
Interest and depreciation, 26% of $2662	= 692.12
Wages, $0.35 × 2808	= 982.80
	$3780.92

Assuming 10% increased earnings, due to adoption of individual motor drive, makes the total earnings:

$4200 + $420 = $4620.00

The net profit is then

$4620 - $3780.92 = 839.08

or 31.5% interest on the investment of $2662.

5 The corresponding figures based on the installation of a new machine tool with individual motor drive are approximately as follows:

Cost of new tool =	$3400.00
Cost of motor etc. =	270.00
	$3670.00
Scrap value of old tool at 5%	160.00
Investment	$3510.00
Overhead operating charge $0.75 × 2808 =	$2106.00
Wages as above	982.80
Interest and depreciation for 10 years (depreciation 10% interest 6%) 16% × $3510 =	561.60
Total	$3650.40

Assuming 25% increased output for the year, the total earnings become

125% × $4200 = $5250.00

Net profit is then $5250 – $3650.40 = $1599.60

or 45.3% interest on the investment.

CONCLUSIONS

6 The above figures show that for the conditions given, approximately 14% greater return on the investment is gained by installation of a complete new tool. It is evident, therefore, that although a somewhat greater capital is required for the new installation, it is by far the better investment. It is also probable that the old machine tools would not last more than five years after the changes were made, whereas the new tools will give good service for at least double that period. Furthermore, the new machine has the added advantage of being in first class condition, thus insuring greater accuracy of workmanship and less liability to accidental delays.

APPENDIX NO. 5. OVERHEAD CHARGES AND MACHINE-HOUR RATES

The following analysis outlines a method of determining the hourly overhead charges per machine tool, which will be called the *machine-hour rates.* Overhead charges can be grouped in three main classes:

A Charges against the entire factory.

a Fixed charges: these include interest and depreciation, taxes and insurance on buildings, grounds and accessories.

TABLE 1 MACHINE HOUR RATES

Type of Machine	Charges per Hour				Depreciation	Power	Total or Mch. Hr. Rate
	Fixed	Variable	Salaries	Interest			
Vertical Boring Mills.							
40-in.-60 in.	$0.02	$0.25	$0.15	$0.05	$0.05	$0.01	$0.53
72 in.-100 in.	0.04	0 45	0.25	0.08	0.08	0.01	0.91
10 ft.-14 ft.	0.05	0.80	0.40	0.15	0.15	0.02	1.57
16 ft.-24 ft. Ext.	0.08	2.00	1.00	0.30	0.30	0.03	3.71
Average per cent of total	3%	52%	28%	8%	8%	1%	100%
Radial drills, 5 ft	$0.02	$0.30	$0.20	$0.03	$0.03	$0.01	$0.59
Radial drills, 10 ft	0.04	0.60	0.35	0.09	0.09	0.01	1.18
Average Per Cent of Total	3%	51%	31%	7%	7%	1%	100%
Engine Lathes:							
30 in.-40 in.	$0.02	$0.25	$0.12	$0.04	$0.04	$0.01	$0.48
40 in.-60 in.	0.03	0.50	0.25	0.10	0.10	0.01	0.99
Average Per Cent of Total	3%	51%	25%	10%	10%	1%	100%
Planers:							
36 in. -56 in.	$0.04	$0.55	$0.30	$0.05	$0.05	$0.01	$1.00
7 ft.-10 ft.	0.06	1.10	0.60	0.15	0.15	0.02	2.08
12 ft.-14 ft.	0.15	2.60	1.40	0.25	0.25	0.03	4 68
Average Per Cent of Total	3%	55%	30%	5.5%	5.5%	1%	100%

b Variable charges: these include repairs and renewals on buildings and accessories, omitting all charges which can be set off directly to a particular section of the factory; charges against the store room and the tool room; defective design, material or workmanship; printing and stationery; lubricants and general manufacturing supplies.

c Salaries (not chargeable to a definite section): these include cost of superintendence (manager, superintendent, foreman); engineering and drawing; clerical force, including office boys and general laborers.

B Charges against each section of the factory.

a Fixed charges; including an equitable portion of the total factory fixed charge and interest, and depreciation on auxiliary apparatus located in the section (except machine tools).

b Variable charges: these include a portion of the variable charges as well as similar charges belonging to the section, such as repairs and renewals, storeroom and tool room charges, defective design, material and workmanship, lubricants and manufacuring supples.

c Salaries: including a portion of the total salaries as well as those belonging exclusively to the section, that is, foremen, clerks, errand boys, laborers, cranemen, etc.

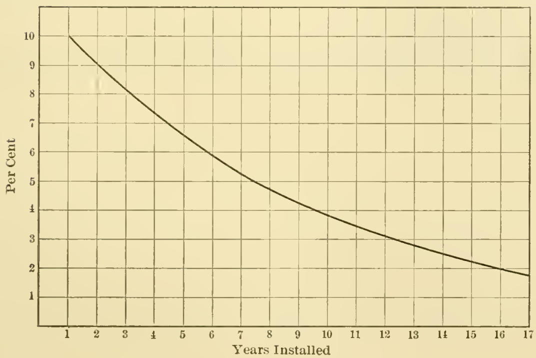


FIG. 1 DEPRECIATION AT 10%, REDUCING BALANCE

C Charges against each machine tool.

a Portion of fixed charge.

b Portion of variable charge.

c Portion of salaries charge.

d Interest on cost of tool, fairly taken at 6%.

e Depreciation of value of tool (see explanation below).

f Cost of power to operate tool, including also lighting and crane service.

DEPRECIATION OF VALUE OF MACHINE TOOLS

2 A method frequently used in calculating the depreciation in value of a machine tool is to allow 10% of a reducing balance; that is, 10% of the first cost if charged off the first year, 10% of the remaining cost, the second year, and 10% of the second remainder the third year, etc. This method is based upon the fact that the apparatus actually decreases in value year by year. Allowance for depreciation in any given year can be made easily by the aid of the curve in Fig. 1. This curve gives the percentage of the first cost corresponding each year to 10% on the reduced balance. For example, the curve shows that the depreciation on a tool that has been in service five years will be 6. 6% of the original cost. If this cost was \$4500, the allowance for depreciation during the sixth year according to the 10% reducing balance method is \$4500 × .066 = \$297. Since this is 10% of the reduced cost, the value of the tool at the end of the fifth year is \$2970.

3 Tools designed for special work will be discontinued after a comparatively limited period, and therefore, depreciate in value much more rapidly than is indicated by the foregoing method: a special allowance frequently made for such tools is generally known as *utility depreciation.*

4 Table 1 contains a summary of machine hour rates obtained by this method. It is assumed that machines have been installed six years, so that the depreciation is 6% on a basis of 10% reducing balance.

GENERAL NOTES

AMERICAN SOCIETY OF CIVIL ENGINEERS

At the meeting of the American Society of Civil Engineers, March 2, in the Society Building, 220 W. 57th Street, New York, a paper entitled, The Improved Water and Sewage Works of Columbus, O., was presented by John H. Gregory.

On March 16th two papers were presented, A Concrete Water Tower by A. Kempkey, Jun.Am.Soc.C.E., and Some Mooted Questions in Reinforced Concrete Design, by Edward Godfrey, Mem.Am.Soc.C.E.

AMERICAN INSTITUTE OF MINING ENGINEERS

The annual convention of the American Institute of Mining Engineers, in which the members of The American Society of Mechanical Engineers were invited to participate, opened on March 1 in the Carnegie Lecture Hall, Pittsburg. In the absence of Julian Kennedy, Dr. John A. Brashear, Mem.Am.Soc.M.E., gave an address of welcome. A great many interesting papers were presented during the three days which followed, including, The Development of Hindered Settling Apparatus, by Prof. R. H. Richards of the Massachusetts Institute of Technology; The Systematic Exploitation of the Pittsburg Coal Seam, by F. Z. Schellenberg of Pittsburg; A Commercial Fuel Briquette Plant, by W. H. Blauvelt of Syracuse, N. Y., Mem.Am.Soc.M. E.; The Gaseous Decomposition Products of Black Powder, by C. M. Young, Lawrence, Kan.; A New Method of Cyaniding Gold and Silver Ores, by E. Gibbon Spilsbury of New York, Mem.Am.Soc.M.E.; The Huronian as a Gold Bearing Terrane, by Dr. Robert Bell, of the Canadian Geological Survey; The Introduction of the Basic Steel Process in the United States, by Geo. W. Maynard of New York; Electric Mine Hoists, by David B. Rushmore of Schenectady, N. Y., Mem.Am.Soc.M.E.; and The Investigations of Structural Materials for Use in Federal Buildings, by E. F. Burchard of the Geological Survey. J. A. Holmes, of the U. S. Geological Survey, Mem. Am. Soc. M. E., also gave a brief paper on the work of the technological branch

at Pittsburg, which was largely explanatory of the plant and work of the survey testing station at Pittsburg. This station was later visited by the members and a series of highly interesting tests were conducted in their presence. Other excursions were also planned and carried out successfully. On the evening of March 2, Dr. D. T. Day of Washington gave a lecture on The Accumulation of Petroleum in the Earth.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The regular monthly meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineering Societies Building, New York, on Friday, March 11, 1910. This meeting was under the auspices of the Industrial Power Committee. Papers were presented as follows: Electric Mine Hoists, by D. B. Rushmore, Mem. Am.Soc.M.E., and K. A. Pauly; and Large Electric Hoisting Plants, by Wilfred Sykes.

Institute Meetings will be held, March 30-April 1, in Charlotte, N. C., and April 21, in San Francisco, Cal. A notice of papers to be read will be found in another department. The next New York Meeting will be held April 8.

CONSERVATION DISCUSSED AT THE NEW HAVEN ECONOMIC CLUB

At a dinner given by the Economic Club of New Haven, Thursday evening, February 24, 1910, The Conservation of our National Resources was presented from different viewpoints by speakers of wide reputation. Calvin W. Rice, Secretary Am.Soc.M.E., spoke on the great work now being conducted by the Government in relation to forests, lands and minerals. He was followed by Charles N. Chadwick, one of the commissioners of the board of Water supply of New York, now constructing an aqueduct from the Catskill mountains to New York City. Mr. Chadwick addressed the gathering on the importance of the conservation of water, upon which the great majority of the other resources are dependent. George W. Woodruff, of New York, former Assistant Attorney-General, emphasized the great economic importance of the preservation of resources. The last speech, by Prof. Herman H. Chapman, acting dean of the Yale Forestry School, dwelt on conservation as related to forests and said that it had been the mission of the United States forest service to actually demonstrate the true meaning of the word conservation as applied to the forests on our public lands in the West.

Among the members and guests present were Henry B. Sargent, Mem.Am.Soc.M.E., Prof. L. P. Breckenridge, Mem.Am.Soc.M.E., Dr. W. L. Phillips, Max Adler, Samuel R. Avis, Dr. Henry Spang.

INSTITUTION OF MECHANICAL ENGINEERS

The Institution of Mechanical Engineers held its annual meeting February 18, 1910, in the institution house, Storey's Gate, St. James's Park, London, S. W., and elected the following officers for the ensuing year: J. A. F. Aspinwall, President, A. T. Tannett Walker and Edward B. Ellington, Vice-Presidents.

The President called upon Dr. Glazebrook of the National Physical Laboratory to resume the discussion on the ninth report to the Alloys Research Committee on The Properties of Some Alloys of Copper, Aluminum and Manganese, presented at the previous meeting by Dr. Rosenhaim and F. C. A. H. Lantsberry. Dr. Glazebrook was followed by Sherard Cowper-Coles, H. F. Donaldson, H. L. Heathcote and Loughnan Pendred, with a closure by Dr. Rosenhaim.

INTERNATIONAL CONGRESS OF INVENTORS

The first annual convention of the International Congress of Inventors will be held in Rochester, N. Y., June 13-18, 1910. This association was established in 1906 and incorporated in 1907, with the aim of uniting the inventors of the world for the purpose of obtaining patent law reforms and protecting the interests of its members. An exhibition of patents and models will be held in connection with the convention, and will include both recent inventions and some of those of particular interest patented during the early years of the U. S. Patent Office.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION

At the eleventh annual convention of the American Railway Engineering and Maintenance of Way Association in Congress Hall, Chicago, Ill., March 15-17, 1910, reports were presented on uniform rules, signals and interlocking; conservation of natural resources; economics of railway location; wood preservation; standard specifications for cement, masonry and buildings, and other subjects of interest.

AIR BRAKE ASSOCIATION

At the seventeenth annual convention of the Air Brake Association to be held in Indianapolis, Ind., beginning May 10, 1910, committee reports will be received on the following topics: Air Brake Instruction, Examination and Rating; Air Pump Piping, Fittings and Connections; Best Arrangement of Air Pump and Main Reservoir Capacity for 100-Car Train Service; Brake Cylinders and Connections and Recommendations for Overcoming Troubles due to Cylinder Leakage; Questions and Answers on New York Brake Equipment; Questions and Answers on Westinghouse Equipment; Recommended Air Brake Practice; Inspection and Cleaning of Triple Valves and Brake Cylinders; the Past Year's Developments in Air Brakes.

AMERICAN ELECTROCHEMICAL SOCIETY

The Spring Meeting of the American Electrochemical Society will be held in Pittsburg, Pa., on May 4-7, 1910. On Wednesday, May 4, at 2.00 p.m., it is proposed to make a visit of inspection to the technological testing plant of the U. S. Geological Survey. Other excursions will be to the Park Company's Crucible Steel Mills, Carnegie Steel Company's Dried Blast Plant at Isabella Furnace, Jones and Laughlin's Steel Works (Talbot Continuous Steel Process), Pennsylvania Lead Smelting Company, Nernst Lamp Factory, Oxy-Actylene Welding Company; with an all-day excursion, visiting the Allegheny Plate Glass Works at Glassmere, Westinghouse Electric Works at East Pittsburg, the Firth-Stirling Works at Demmler (Heroult electric steel furnace in operation), Carnegie Steel Works at Homestead (combined open-hearth electric furnace in operation).

This is the first gathering of the society at Pittsburg. A fine program and a highly interesting meeting is assured.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

At the regular monthly meeting of the Engineers' Society of Western Pennsylvania, held March 15, 1910, President E. K. Morse, in response to a request made by the Pittsburg Chamber of Commerce, appointed the following Committee to report on the question of raising the bridges over the Allegheny River at Pittsburgh: Geo. S. Davison, Mem.Am.Soc.C.E.; Julian Kennedy, Mem.Am.Inst.M.E.; F. L. O. Wadsworth, Mem.Am.Soc.M.E.; John N. Chester, Mem.Am.Soc.-

M.E.; Emil Gerber, Mem.Am.Soc.C.E. The importance of the questions involved, both engineering and financial, may be realized from the fact that there are eight bridges affected, over a river averaging 1000 feet in width. A paper on Floods in the River Seine was read by Thos. P. Roberts of the U. S. Engineer's Office, Pittsburg.

IDAHO SOCIETY OF ENGINEERS

On February 12 the Idaho Society of Engineers was organized at Boise, Idaho, with 70 charter members representing surveyors and the four leading branches of engineering. It is the outgrowth of the Idaho Civil Engineers and Surveyors Association, and has been organized mainly through the work of Gen. Darwin A. Utter, United States surveyor-general for the State, who was elected president. In addition to the work of organization, papers were read on Dam Building, Railroad Construction, Water Power, Milling Ores, Irrigation and Municipal Engineering. Meetings will be held at Boise on the second Tuesday of each month.

UNIVERSITY OF KANSAS

The new engineering buildings of the University of Kansas were formally dedicated on February 25, 1910, in the presence of some 500 visitors, including alumni, engineers from other schools, and other interested persons. The program included three addresses in the chapel in the afternoon, by Prof. F. O. Marvin, Dean of the School of Engineering, Prof. Richard C. Maclaurin, President of Massachusetts Institute of Technology, and Ernest R. Buckley, President of the American Mining Congress. The dedication ceremony itself was held a little later, in the new mechanical and electrical engineering building, and was followed by a banquet at the Robinson gymnasium in the evening.

DETROIT INDUSTRIAL EXPOSITION

The city of Detroit, Mich., is planning a great industrial exposition to be held under the auspices of the Board of Commerce, June 20-July 6, 1910. The exposition ground will be located on the Detroit River where a huge building will be erected and used in conjunction with the Wayne Pavilion. The display promises to be one of the most unique ever arranged outside of a world's fair. It is claimed that 100,000

different articles are manufactured in the 3000 shops of the city, the products ranging from pins to steamships, a variety rivaled by the outputs of few other American cities. The processes as well as the results will be shown, with the purpose of teaching the world the variety, extent and quality of the city's products. The committee in charge is composed of 275 of the leading manufacturers of Detroit.

PERSONALS

Henry A. Allen has been appointed consulting engineer for the Department of Public Works, Chicago, Ill.

F. E. Bocorselski, who has been connected with the Baush Machine Company as superintendent and designer, has resigned his position to become assistant mechanical superintendent of the American Locomotive Company, with headquarters at Richmond, Va.

Claude A. Bulkeley, chief engineer of the board of education, St. Louis, Mo., has become associated with the firm of Marks & Woodwell, New York.

I. Francis Burton, formerly assistant superintendent of the Victor Talking Machine Company, Philadelphia, Pa., has been appointed superintendent of the company.

Charles F. Dixon has become connected with the engineering department of the New England Engineering Company, New Haven, Conn.

John M. Ewen has resigned his position as harbor commissioner of Chicago, Ill.

E. S. Farwell, consulting engineer, of New York, has become connected with the Yellow Pine Paper Mill Company, Orange, Tex., as general manager.

M. P. Fillingham, consulting engineer, New York, has assumed charge of the Eastern interests of the Fawcus Machine Company, of Philadelphia, Pa.

Francis L. Gilman, formerly associated with the American Telephone and Telegraph Company, New York, has become general manager of the Missouri and Kansas Telephone Company, Kansas City, Mo.

George P. Gilmore, recently local engineer of the American Thread Company, Fall River, Mass., has opened a power and equipment engineering office in the same city.

B. S. Hughes has severed his direct connection with the Champion Coated Paper Company, Hamilton, O., and the Champion Fibre Company, Canton, N. C., to engage in general engineering practice, with offices in Cincinnati, O.

F. W. Jackson, formerly district manager for the Harrisburg Foundry and Machine Works, Baltimore, Md., has been transferred to the managership of the company's business at Chicago.

Walter C. Kerr has been elected third vice-president of the Merchants' Association of New York.

Alfred H. Knight has become connected with the Packard Motor Car Com-

pany, Detroit, Mich. as carriage chassis engineer. He was until recently assistant professor of mechanical engineering at the University of Michigan, Ann Arbor, Mich.

F. E. Matthews, consulting refrigerating engineer, New York, has become assistant manager of the cold storage insulation department of H. W. Johns-Manville Co., New York.

Geo. R. Murray has been appointed president of the Murray Stone Co., successors to the Maxwell-Rolf Stone Company.

John C. Parker, electrical engineer for the Rochester Railway and Light Company, has been appointed non-resident lecturer in electric energy transmission at the University of Michigan, Ann Arbor, Mich.

W. P. Pressinger, formerly identified with the W. P. Pressinger Company, New York, has been appointed vice-president and manager of sales of the Keller Manufacturing Company, Philadelphia, Pa.

Paul S. Rattle, mechanical engineer of B. M. Osbun Co., Chicago, Ill., has become associated with the sales organization of the Hicks Locomotive and Car Works, Chicago.

Robert W. Rogers, formerly identified with the Erie Railroad, Meadville, Pa., has entered the service of the C. A. Stickney Co., St. Paul, Minn., as mechanical engineer.

Clement F. Smith, recently associated with the Westinghouse Air Brake Company, Wilmerding, Pa., has opened an office in Cleveland, O.

Ephraim Smith, who has been the New England sales manager of the Colonial Steel Company since its organization in 1901, has resigned his position on account of ill health.

Roy B. Smith has become inspector of the Pennsylvania Lines, West, Columbus, O. Until recently he was foreman of motive power and equipment of the C. L. & N. Railway, Cincinnati, O.

B. V. Swenson has become connected with Barron G. Collier. Inc., New York. He was formerly secretary and treasurer of the American Street and International Railway Association, New York.

Cary D. Terrell, formerly assistant manager of sales of the Pressed Steel Car Company, St. Louis, Mo., has become sales agent of the American Car and Foundry Company, St. Louis, Mo.

Henry R. Towne has been elected president of the Merchants' Association of New York.

Theron H. Tracy, president of the Tracy-Devereaux Co., Los Angeles, Cal. has been appointed president of the Durostone Company of America, San Diego Cal.

A. W. Waern has become associated with Jos. H. Wallace & Co., New York.

He was formerly engineer of the machinery department of the Bethlehem Steel Company, South Bethlehem. Pa.

Prof. Ira H. Woolson, adjunct professor of civil engineering, Columbia University, in charge of fire tests of building materials, has resigned to become consulting engineer for the National Board of Fire Underwriters.

Roydon V. Wright, for several years managing editor of the American Engineer and Railroad Journal, has become a member of the editorial staff of the Railway Age Gazette, with direct supervision over the mechanical department

CURRENT BOOKS

The Economy Factor in Steam-Power Plants. By George W. Hawkins. *Hill Pub. Co., New York, 1908.* Cloth, 8vo., ix+ 133 pp., illustrated. Price, $3 net.

Contents: Introduction; Part I, Individual Apparatus: Boilers, Engines, Electrical Generators, Condensing Apparatus, Feed-Pumps, Oil-Pumps, Oil Burners, Radiation, Leakage, Feed-Water Heaters, Fuel Economizers; Part II, The Factor of Evaporation; Part III, Complete Plant Economy (Full Rated Load): Introductory, Non-Condensing Plants, Surface-Condensing Plants, Jet-Condensing Plants, Pumping Plants, Examples; Part IV, Complete Plant Economy (Variable Load): Phases of the Problem, Method of Solution; Conclusion.

The Gas Turbine. Progress in the Design and Construction of Turbines Operated by Gases of Combustion. By Henry Harrison Suplee, B.Sc. *J. B. Lippincott Co., Philadelphia, 1910.* Cloth, 8vo., 262 pp., with diagrams. Price, $3.

Contents: Introduction; Historical; Discussion before the Institution of Mechanical Engineers; Discussion before the Society of Civil Engineers of France; Actual Behavior of Gases in Nozzles; Practical Work of Armengaud and Lemale; General Conclusion.

Heat Energy and Fuels. Pyrometry, Combustion, Analysis of Fuels and Manufacture of Charcoal, Coke and Fuel Gases. By Hanns v. Jüptner. Translated by Oskar Nagel, Ph.D. *New York, McGraw Pub. Co.,1908.* Cloth, 8vo., 306 pp., illustrated. Price, $3.

Contents: Introduction: General Remarks, Forms of Energy. Vol. I. Heat Energy and Fuels. Part I. Heat Measurement, Combustion and Fuels: The Measurement of High Temperatures (Pyrometry); Pyrometry, Optical Methods of Measuring Temperatures; Combustion Heat and its Determination; Direct Methods for Determining the Combustion Heat; Incomplete Combustion: Combustion Temperature; Fuels (in general); Wood; Fossil Solid Fuels (in general); Peat; Brown Coal (Lignite); Bituminous and Anthracite Coals; Artificial Solid Fuels; Charcoal; Peat-Coal, Coke and Briquettes; Coking Apparatus; Liquid Fuels; Gaseous Fuels; Producer Gas; Water Gas; Dowson Gas, Blast Furnace Gas and Regenerated Combustion Gases; Apparatus for the Production of Fuel Gases.

The Resistance and Propulsion of Ships. By William F. Durand. Second edition, thoroughly revised. *New York, John Wiley & Sons, 1909.* Cloth, 8vo., vii + 427 pp. Price, $5.

Contents: Resistance; Propulsion; Reaction between Ship and Propeller; Propeller Design; Powering Ships; Trial Trips.

The Modern Gas Engine and the Gas Producer. By A. M. Levin. First edition. *New York, John Wiley & Sons, 1910.* Cloth, 8vo., 16 + 485 pp., illustrated. Price, $4.

Contents: Introduction to Thermodynamics; Design Constants and Formulas; Theoretical Analyses of the Gas-Engine Cycles; Power, Size and Speed of Gas-Engines; Fuels, Combustion; Gas-Engine Fuels—The Proportioning of Mixtures and Relation of these to the Size of the Engine; Alcohol Fuels; Features of the Practical Gas-Engine Cycle; The Fly-Wheel; The Crank Shaft; Engines Details; Governing; Engine Auxiliaries; Various Engine Types; Producer-Gas and Gas-Producers; Appendix.

Fulfilment of Three Remarkable Prophecies in the History of the Great Empire State, Relating to the Development of Steamboat Navigation and Railroad Transportation, 1808–1908. By Henry Whittemore. Cloth, 8vo., 80 pp.

Contents: Early Experiments in Steamboat Navigation; James Rumsey's Claim to the Discovery of Steamboat Navigation; Claims of Nathan Read, Nicholas Roosevelt, Capt. Samuel Morey and Elijah

Ormsbee; Inventions of Col. John Stevens and Robert L. Stevens in Steam Navigation; Robert Fulton–His Successful Efforts in the Development of Steam Navigation with the Assistance of Robert L. Livingston; Improvements in Steamboats and Increased Facilities for Steam Navigation on the Hudson River; Rivalry between Steamboat Companies—Steamboat Disasters—Great Improvement in Steamboat Construction; Railroad Transportation.

AUTOMOBILES. By Hugo Diemer, M.E. *Chicago, American School of Correspondence, 1909.* Cloth, 192 pp., illustrated. Price, $1.50.

Contents: Component Parts of a Motor-Car; Power Plant of a Gasolene Car; Controlling Mechanism and Transmission; Care and Operation of Motor-Cars; Selection and Classification of Motor-Cars; Index.

TABLES AND DIAGRAMS OF THE THERMAL PROPERTIES OF SATURATEDAND SUPERHEATED STEAM. By Lionel S. Marks and Harvey N. Davis. *New York, Longmans, Green & Co., 1909.* Cloth, 8vo., 106 pp.,illustrated. Price, $1, net.

Contents: Part I: Tables and Diagrams; Part II: The Use of the Diagrams; Part III: Discussion of Sources.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. List of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

American Mining Congress. Monthly bulletin. Vol. 13, no. 2. *Denver, 1910.*

American Water Works Association. Proceedings, 1909. *Baltimore, 1909.* (Gift of American Water Works Association.)

Approximate Cost of Mill Buildings. By C. R. Main. *Waltham, 1910.*

Automobiles. By Hugo Diemer. *Chicago, 1909.* (Gift of author.)

Beiträge zür Geschichte der Technik und Industrie. Vol. 1, 1909. *Berlin, Springer, 1909.* (Gift of Verein deutscher Ingenieure.)

Broadening the Field of the Marine Steam Turbine: the Problem and its Solution. The Melville and Macalpine Reduction Gear. *Pittsburg, 1909.*

Carnegie Institution of Washington, Department of Terrestrial Magnetism. Annual report of the director, 1909. (Gift of the Department.)

Civil Engineer's Pocket-book. Ed. 19. By J. C. Trautwine. *New York, J. Wiley & Sons, 1909.* (Gift of J. C. Trautwine, Jr., and J. C. Trautwine, 3d.)

Control of Flies and Other Household Insects. Bulletin 136, N. Y. State Museum. By E. P. Felt. *Albany, 1910.*

Design and Construction of Internal-Combustion Engines. By Hugo Guldner. *New York, 1910.*

Deutsch-Amerikanischen Techniker-Verbandes. Verbands-Statuten, 1910. *New York, 1910.*

Dictionnaire de la Langue Française. Vol. 1–4 and supplement. *Paris, 1884–1885.*

Economy Factor in Steam-Power Plants. By G. W. Hawkins. *New York, Hill Publishing Co., 1908.*

Elements of Machine Design. Part 1, General principles, strength of materials, etc. *London, 1909.*

Elevator Service. By R. P. Bolton. *New York, 1908.*

Energy: Work, Heat and Transformations. By S. A. Reeve. *New York, McGraw-Hill Book Company, 1909.*

Engineers' and Firemen's License Law. Boiler Inspection Law. Rules Formulated by the Board of Boiler Rules, Commonwealth of Massachusetts. *Boston, 1909.* (Gift of John A. Stevens.)

Gas Engine. By C. P. Poole. *New York, Hill Publishing Co., 1909.* (Gift of author.)

Die Gasmaschine. Ed. 5. By R. Schöttler. *Berlin, 1909.*

Gas Turbine. By H. H. Suplee. *Philadelphia, 1910.* (Gift of author.)

Grossgasmaschinenbau in Amerika. By Dr. Rieppel, Jr. (Reprint Zeitschrift Vereines deutscher Ingenieure, 1909.) (Gift of author.)

Handbook of Small Tools. By Erik Oberg. *New York, 1908.*

Heat Energy and Fuels. By Hanns v. Juptner. *New York, McGraw Publishing Co., 1908.*

Henley's Encyclopædia of Practical Engineering and Allied Trades. Vol. 5 (Spe-Z). *New York, N. W. Henley Publishing Co., 1909.*

Hydraulic Elevators. By Wm. Baxter, Jr. *Chicago, 1905.*

Illustrated Technical Dictionary. Vol. 5, Railway construction and operation; Vol. 6, Railway rolling stock. *New York, 1909.*

Large Gas Engines. By P. R. Allen. (Reprinted from Cassier's Magazine, July-September 1909.) (Gift of Cassier's Magazine.)

Linseed Oil and Other Seed Oils. By W. D. Ennis. *New York, D. Van Nostrand Co., 1909.*

Losses off Transmission Lines, Due to Brush Discharge, with Special Reference to the Case of Direct Current. (Institution of Electrical Engineers, 1909.) (Gift of Calvin W. Rice.)

Millwrighting. By J. F. Hobart. *New York, 1909.*

Modern Electric Time Service. By F. H. Jones. (Institution of Electrical Engineers, 1909.) (Gift of Calvin W. Rice.)

Modern Gas-Engine and the Gas-Producer. By A. M. Levin. *New York, J. Wiley & Sons, 1910.*

Motor Traction. Vol. 9, no. 421-date. *London, 1909-date.*

New York City, Department of Bridges. Report on Manhattan Bridge. By Ralph Modjeski. 1909. *New York, 1909.* (Gift of the Department.)

Postulados de las Clases Obreras y de los Descalidos y Proletarios, a Presencia de la Ciencia Social y, en especial, de la economia politica. Vol. 2. *Santiago de Chile, 1909.* (Gift of Secretary-General, Fourth Scientific Congress [First Pan-American].

Practical Cold Storage. By Madison Cooper. *Chicago, 1905.*

Princeton University. Directory of Living Graduates and Former Students, 1908. *Princeton, 1908.*

Producer-Gas-Fired Furnaces. By Oscar Nagel. *New York, 1909.*

Resistance and Propulsion of Ships. Ed. 2. By W. F. Durand. *New York J. Wiley & Sons, 1909.*

Smithsonian Institution. Annual report. 1908. *Washington, 1909.*

Société des Ingenieurs Civils de France. Inauguration du Nouvel Hotel, January 1897. *Paris, 1897.*

Steam Power Plant Piping Systems. By W. L. Norris. *New York, 1909.*

Tables and Diagrams of the Thermal Properties of Saturated and Superheated Steam. By L. S. Marks and H. N. Davis. *New York-London, Longmans, Green & Co., 1909.* (Gift of author.)

Theory and Practice of Modern Framed Structures. Part 1, Stresses in simple structures. Ed. 9. By J. B. Johnson, C. W. Bryan and F. E., Turneaure. *New York, 1910.*

Types and Details of Bridge Construction. Parts 1–3. By F. W. Skinner. *New York, 1904, 1906, 1908.*

U. S. Library of Congress. Duplicate periodicals and serials available for exchange January 1910. *Washington, 1910.*
———Want list miscellaneous publications 1909. *Washington, 1909.*

U. S. Library of Congress. Report of Librarian, 1909. *Washington, 1909.*
———Publications issued since 1897. *Washington, 1910.*

University of Pennsylvania. Catalogue, 1909–1910. *Philadelphia, 1910.*
Verein deutscher Ingenieure. Zur feier des 50 jährigen bestehens des vereines. 1856–1906.

———Berliner bezirtsverein deutscher Ingenieure. 1856–1906. *Berlin, 1900.*

Watuppa Water Board. 36th Annual Report. *1910.*

EXCHANGES

Junior Institution of Engineers. Journal and Record of Transactions. Vol. 19. *London, 1909.*

Liverpool Engineering Society. Transactions. *Liverpool, 1909.*

Railway Signal Association. List of Members, 1910. *Bethlehem, 1910.*

Sächsischer Dampfkessel Revisions Verein, Chemnitz. Ingenieur-Bericht, 1909. *Chemnitz.*

TRADE CATALOGUES

American Spiral Pipe Works, *Chicago, Ill.* Spiral riveted pipe, forged steel pipe flanges, hydraulic and exhaust steam supplies, 20 pp.

Asbestos Protected Metal Co., *Canton, Mass.* Asbestos protected metal for roofing, siding, ceiling, and interior finish, 8 pp.

Economy Drawing Table Co., *Toledo, O.* Drawing tables, sectional filing cases and specials in this line, for engineers, architects, contractors, manual training schools, etc., 48 pp.

General Electric Co., *Schenectady, N. Y.* Building lighting with general electric tungsten and tantalum lamps, 16 pp. Price list No. 5211, G. E. tantalum incandescent lamps, 5 pp.; November 1909, Index to bulletins published, 9 pp.; Bulletin No. 4703A, Variable release air brake equipment, 11 pp.; Bulletin No. 4714, Railway signal voltammeter, type S, 3 pp.; Bulletin No. 4715, G. E. 210 Railway motor, 16 pp.

Hagan Gas Engine & Mfg. Co., *Winchester, Ky.* Catalogue C, 2 to 100 h.p. Hagan gas and gasolene engines, 39 pp.

Jeffrey Mfg. Co., *Columbus, O.* Booklet No 33, Jeffrey wire cable conveyors, 24 pp.; Booklet No. 34, Jeffrey standard elevator buckets, 24 pp.

Lamson Consolidated Store Service Co., *Boston, Mass.* Two-wire cord-propulsion parcel carriers for stores, 8 pp.

Manufacturing Equipment and Engineering Co., *Boston, Mass.* All-metal, sanitary, and fireproof equipment for factories, foundries, offices, hospitals, etc., 32 pp.

National Vacuum Heating Co., *Marshalltown, Iowa.* Dunham vacuo-vapor system of heating, 40 pp.

Northwestern Expanded Metal Co., *Chicago, Ill.* Reinforcing for sewers, tanks, and walls, 16 pp.

Ohio Brass Co., *Mansfield, O.* Bulletin of electric railway and mine haulage material, 24 pp.

Remington Typewriter Co., *New York, N. Y.* Remington Notes, vol. 2, No. 2, containing notes of interest to users of the Remington typewriter, 16 pp.

Francis H. Richards, *New York, N. Y.* Useful information concerning patents and inventions, 38 pp.

Russel Wheel and Foundry Co., *Detroit, Mich.* Views of Russel skidding and loading machines in operation, 40 pp.; catalogue of different styles and patterns of Russel cars for handling logs, lumber, etc., 46 pp.

Joseph T. Ryerson & Sons, *Chicago, Ill.* March, 1910. Ryerson Monthly Journal and Stock List of iron and steel supplies, 144 pp.

Chas A. Stickney Co., *St. Paul. Minn.*, Bulletin No. 1137, The Stickney oil engine and 57 points in which it excels other engines, 16 pp.

Underfeed Stoker Co. of America. *Chicago, Ill.* Publicity Magazine, February 1910, devoted to the interests of the Jones mechanical stoker, 15 pp.

Wagner Electric Mfg. Co., *St Louis, Mo.* Bulletin 89—Type BW polyphase induction motor, 8 pp.

Warner & Swasey Co., *Cleveland, O.* Warner & Swasey prism terrestrial telescope, 3 pp.

UNITED ENGINEERING SOCIETY

GIFT OF E. E. OLCOTT

ALBANY INSTITUTE. Transactions. Vol. 5. *Albany, 1867.*

NEW YORK STATE. Adjutant General. Annual report. Vol. 3. *Albany, 1868.*

NEW YORK STATE ENGINEER AND SURVEYOR. Annual report on canals. 1862, 1864. *Albany, 1863, 1865.*

———Annual report on railroads. 1862, 1865. *Albany, 1863, 1866.*

NEW YORK STATE RAILROAD COMMISSIONERS. Report, Vol. 1, 1885. *Albany, 1886.*

SWEET, S. H. Documentary sketch of New York State canals. *Albany, 1863.*

REGISTER TILL PATENT MEDDILADE AF KUNGL. PATENTBYRAN. 1885–1908 and supplement to 1905. *Stockholm, 1890–1909.*

TRADE CATALOGUES

GIROD FURNACES, *Ugine, Savoie.* Steels made by the Girod process, 16 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

015 Sales manager for improved type of heavy-duty gas and gasoline engines, up to 25 h.p., for industrial and farm purposes. Applicant should state experience in similar capacity and what results he could agree to produce.

016 Large blast-furnace plant in the South wants at once draftsman between twenty-five and thirty years old, technically educated, with sufficient breadth to do testing and various work about the plant. Climate agreeable and healthful. Exceptional opportunity for the right man.

017 Wanted, by a large iron and steel company, superintendent of shops; include pattern, foundry, blacksmith, pipe and machine shops; combined force of about 500 men. Prefer technically educated man. Must be an organizer, familiar with modern methods and able to hold production costs on reasonable basis. None but high class man need apply. Salary $3600 per annum.

018 Wanted: thorough practical and theoretical man, to take charge of the production and the development of a concern located in the Middle West, manufacturers of injectors, valves, etc. Must be familiar with railroad operating conditions and thoroughly up-to-date in brass foundry and machine shop practices.

019 Instructor in mechanical drawing and machine design in a technical school near New York. Previous teaching experience desirable but not essential. Salary about $1500 with good opportunity for advancement.

020 Assistant engineering editor on prominent trade journal; excellent opportunity for rapid advancement. State experience fully; communications confidential.

021 Opportunity for engineer with business experience to acquire interest in business of manufacture of all classes of hydraulic machinery, steam hammers, etc. Location Pennsylvania.

MEN AVAILABLE

41 Lawyer-engineer, desires position as salesman. Age 44; member United States Supreme Court; legal and technical education, twenty-five years successful experience combined with sales, steam, electrical and gas driven power plants, water and gas works, chemicals, every description of machinery and its product; specialty, automobile salesman. Extensive acquaintance throughout the United States.

42 University graduate in mechanical engineering, a student member, located on the Pacific Coast, desires position with eastern gas engine company; at present designing medium and large liquid fuel engines, stationary and marine; testing and machine shop experience.

43 Junior member, graduate mechanical and electrical engineer, Mass. Inst. of Technology; experience in erection and operation of electric power plants; has served time in large railroad shops and understands shop methods thoroughly. Location immaterial.

44 Mechanical engineer, specialized in manufacturing, thoroughly competent to take responsible position. As superintendent and manager has successful practical experience in foundry and machine shop; gray iron and brass mixtures by analysis, machine molding, interchangeable machine work, systematizing, cost-keeping, piece work, etc.; knows how to equip plant and organize men to secure large output and low costs.

45 Cornell graduate, married, nine years' experience with engineers, contractors and industrial companies, in drafting room, office and on construction; desires to make a change.

46 Mechanical engineer, Member, technical graduate; broad practical knowledge of engineering, good systematizer, especially able as a producer, severa- years' experience in engineering work, in charge of large engineering departl ments; desires position with first-class firm as chief engineer, or similar position.

47 Man with seventeen years' experience in office and shop of manufacturing concern, general experience in this line and executive work; would like to meet some responsible concern in New York or vicinity who want salesman or competent office manager.

48 Engineer, thirty years old, technical graduate, desires position preferably in Chicago, as factory manager of a small but growing plant. Four years' shop and drafting experience, four years installing cost and shop systems, experienced in laying out and constructing power plants and industrial works.

49 Member, with over twenty years' practical experience in designing, superintending and managing work in shop and field, desires position, preferably near Philadelphia.

50 Engineer, wants the New York agency for the best automobile delivery wagon and automobile truck in the United States.

51 Member, now general mechanical superintendent, desires change. Ten years' experience as mechanical engineer and superintendent, general transmission machinery, gas and Corliss engines. Thoroughly posted on rapid foundry, machine shop production and up-to-date appliances and methods.

52 Associate member, twenty-eight years of age, graduate marine and mechanical engineer, wishes to locate with some good, growing manufacturing concern in capacity of chief engineer, assistant chief engineer, chief draftsman or similar position, where the services of a mechanical engineer with an excellent theoretical, as well as practical training in the gas engine, producer, steam engine, power transmission and general engineering lines will be appreciated. Best references as to ability and character.

53 Associate, graduate mechanical engineer, fourteen years' experience in general engineering work, including machine shop work, testing, power plant design, construction and operation. Five years in electric railway work, involving civil, mechanical and electrical engineering; recently completed the remodeling of an electric railway and lighting power plant, now completing the construction of a large electric power plant. Good executive ability, experience in office methods, correspondence, etc. Wishes an executive position involving responsibility. Salary $2500.

54 Junior, technical graduate, at present mechanical engineer and assistant to manager of plant building high grade boilers. Experienced boiler designer. Desires similar position, or as assistant superintendent in large plant.

55 Junior member, age thirty-one, desires to make a change. Several years designing, testing and installing steam turbines, steam engines, condensers, etc.; varied experience in engineering lines, and electrical work. Desires position with large industrial corporation, or in office of consulting or contracting engineer.

56 Graduate mechanical engineer. Harvard University, S.B. and M.M.E., twenty-five years of age, experienced in the organization and management of work shops, would like to obtain position with establishment manufacturing standard line of goods, or with consulting engineer engaged in workshop organization and management.

57 Member, desires position as mechanical engineer with concern developing new inventions; competent in designing, perfecting and simplifying mechanisms.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALDEN, Herbert W. (1908), Ch. Engr., Timken-Detroit Axle Co., Clark Ave., Detroit, Mich.

BORDEN, Wm. H. (Junior, 1905), Goldsboro, N. C., and *for mail*, 713 Seventh Ave., N., Seattle, Wash.

BULKELEY, Claude A. (1909), Cons. Mech. and Elec. Engr., 511 Terminal Bldg., 41st St. and Park Ave., New York, N. Y.

BURTON, Isaac Francis (1908), Supt., Victor Talking Mch. Co., and *for mail*, 5219 Walnut St., Philadelphia, Pa.

BUSH, Harold Montford (1894; 1905), Cons. Engr., 69 N. Fourth St., Columbus, O.

CAMPBELL, Jeremiah (Associate, 1896), 2 New St., East Boston, Mass.

CHESS, Harvey B., Jr. (Junior, 1909), Secy. and Wks Mgr., Consolidated Expanded Metal Cos., Rankin, and *for mail*, 814 Aiken Ave., Pittsburg, Pa.

COFFIN, Howard E. (1907), V. P., Hudson Motor Car Co., and 434 Cadillac Ave., Detroit, Mich.

DIXON, Charles F. (Junior, 1903), Engrg. Dept., New England Engrg. Co., 113 Church St., and *for mail*, 172 Ellsworth Ave., New Haven, Conn.

DOUGLASS, Wm. M. (1884), 306 Seventh Ave., Bethlehem, Pa.

FARWELL, E. S. (1899), Genl. Mgr., Yellow Pine Paper Mill Co., Orange, Tex.

FLEMING, Wills M. (1905; 1909), Ch. Draftsman, Deane Steam Pump Co., and *for mail*, 370 Maple St., Holyoke, Mass.

GILMAN, Francis L. (1908), Genl. Mgr., Missouri & Kansas Telephone Co., Kansas City, Mo.

GILMORE, George Parley (1909), Power and Equip. Engr., First Natl. Bank Bldg., and *for mail*, 109 Barre St., Fall River, Mass.

HILL, Robert J. (Associate, 1904), 810 Marquette Bldg., Chicago, and 816 Sheridan Road, Wilmette, Ill.

HORTON, William H. (Junior, 1904), 7001 S. Park Ave., Chicago, Ill.

HUGHES, Burton Shelley (1908), Cons. Engr., 1014 Commercial Tribune Bldg., Cincinnati, O.

JACKSON, F. W. (1909), Dist. Mgr., Harrisburg Fdy. & Mch. Wks., 950 Marquette Bldg., Chicago, Ill.

KEITH, Thomas M. (Junior, 1905), Robins Conveying Belt Co., Park Row Bldg., New York, N. Y.

KNIGHT, Alfred H. (1909), Carriage Chassis Engr., Packard Motor Car Co., and *for mail*, 185 Seward Ave., Detroit, Mich.

LEE, Ralph A. (Junior, 1909), Asst. Bldg. Supt., with Walter Kidde, 140 Cedar St., New York, and *for mail*, 578 75th St., Brooklyn, N. Y.

LEE, Robert E. (Junior, 1907), 129 Chestnut St., Rutherford, N. J.

MATTHEWS, Fred Elwood (Junior, 1904), Asst. Mgr., Cold Storage Insulation Dept., H. W. Johns-Manville Co., 100 William St., New York, N. Y.

MEINHOLTZ, Herman Chas. (1909), V. P. and Supt., Heine Safety Boiler Co., 2449 E. Marcus Ave., and *for mail*, 4812 Greer Ave., St. Louis Mo.

MILLETT, Kenneth B. (Junior, 1908), Factory Supt., Protal Co., Bridgeport, Conn.

MINCK, Peter (Junior, 1909), Mech. Engr., with Edwin Burhorn, 71 Wall St., New York, N. Y., and *for mail*, 112 Gardner St., Union Hill, N. J.

MURRAY, Geo. R. (1903), Pres., Murray Stone Co., 914 Williamson Bldg., Cleveland, O.

MURRIE, John L. (Junior, 1905), Mech. Engr., Pub. Service Com., First Dist., Tribune Bldg., and *for mail*, 551 W. 178th St., New York, N. Y.

ORD, Henry C. (1905), Genl. Elec. Co., and *for mail*, 3 Eastern Ave., Lynn, Mass.

POULTNEY, John Livingston (1908), Contr. Engr., Land Title Bldg., Philadelphia, Pa.

POWELL, E. Burnley (Junior, 1904), Stone & Webster Engrg. Corp., 147 Milk St., Boston, Mass., and *for mail*, Houghton County Elec. Light Co., Houghton, Mich.

RATTLE, Paul S. (Junior, 1908), Sales Organization, Hicks Loco. & Car Wks., Chicago, and 459 Oak Park Ave., Oak Park, Ill.

REID, John Simpson (1898), Instr. Mech. Drawing and Design, Armour Inst. Tech., and 43 W. 33d St., Flat C, Chicago, Ill.

RICE, Alva C. (1890), Cons., Hyd. and Mech. Engr., 5 Oberlin St., Worcester, Mass.

ROUVEL, George W. (1907), Genl. Supt., Standard Portland Cement Co., Napa Junction, and Napa, Cal.

SERGEANT, Chas. H. (1895), 511 W. 134th St., New York, N. Y.

SMITH, Roy B. (Junior, 1905), Inspr., Pa. Lines West, and *for mail*, 106 S. Champion Ave., Columbus, O.

TALCOTT, Robt. Barnard (1907), Inspr. Mech. and Elec. Engrg., U. S. Post Office Bldg., Denver, Colo.

TAYLOR, Percy B. (1909), Cons. Engr., 196 Market St., Newark, N. J.

TERRELL, Cary D. (Junior, 1901), Sales Agt., Am. Car & Fdy. Co., 915 Olive St., St. Louis, Mo.

TRACY, Theron H. (1902), Pres., Durostone Co. of America, San Diego, Cal.

UNGER, John S. (1886), Cons. Engr., 1412 N. Y. Life Bldg., and *for mail*, 3344 Evanston Ave., Chicago, Ill.

WAERN, A. W. (1908), Cons. Engr., Jos. H. Wallace & Co., Temple Court Bldg., New York, N. Y.

WALSH, Thomas J. (Junior, 1906), Stone & Webster Engrg. Corp., Boston, Mass., and *for mail*, Houghton County Elec. Light Co., Houghton, Mich.

WILDER, Clifton W. (1907), Asst. Elec. Engr., Pub. Service Com., 154 Nassau St., New York, N. Y.

WRIGHT, Roydon V. (1907), Supv. Mech. Dept., Railway Age Gazette, New York, N. Y., and *for mail*, 285 N. 20th St., East Orange, N. J.

NEW MEMBERS

BLANCHARD, Henry W. (1909), Mgr., Austral Iron Wks., E. W. Tarry Co., Ltd., and *for mail*, P. O. Box 1098, Johannesburg, Transvaal, South Africa.

RUCKER, B. Parks (1909), Elec. and Mech. Engr., Trust Bldg., Charlotte, N. C.

STODDARD, Elliott J. (1909), Parker & Burton, 603 Moffat Bldg., Detroit, Mich.

PROMOTIONS

HVID, Rasmus M. (1907; Associate, 1909), Am.Soc.M.E., 29 W. 39th St., New York, N. Y.

THURN, Theodore (1904; 1909), Engr., Genl. Elec. Co., 23 Water St., Yokohoma, Japan.

DEATHS

GOODALE, A. M., December 17, 1909.

GAS POWER SECTION

CHANGES OF ADDRESS

FLEMING, W. M. (1909), Mem.Am.Soc.M.E.
MATTHEWS, Fred E. (1908), Mem.Am.Soc.M.E.
MYERS, Theodore B. (Affiliate, 1909), 981 Bulls Ferry Rd., Woodcliff-on-Hudson, N. J.
SERGEANT, Chas. H. (1908), Mem.Am.Soc.M.E.
UNGER, John S. (1909), Mem.Am.Soc.M.E.
WILDER, Clifton W. (1908), Mem.Am.Soc.M.E.

NEW MEMBERS

BIGELOW, Lucius S. (Affiliate, 1910), Pres., Light Pub. Co., 106 Fulton St., and Pres., Periodicals Pub. Co., New York, N. Y.
HARRIS, William J., Jr. (Affiliate, 1910), Junior Engr., Tech. Branch, U. S. Geolog. Survey, Washington, D. C.
HOBART, Frank G. (1910), Mem.Am.Soc.M.E.
IRWIN, Arthur Charles (Affiliate, 1910), Erecting Engr., Tait Producer Co., New York, and *for mail,* 33 E. Smith Ave., Corona, L.I., N. Y.
KENNEY, Lewis H. (1910), Mem.Am.Soc.M.E.
MYERS, David M. (1910), Mem.Am.Soc.M.E.
RANDALL, Dwight T. (1910), Mem.Am.Soc.M.E.
SMITH, Earl B. (Affiliate, 1910), Asst. Prof. Expl. Mech. Engrg., Drexel Inst., Philadelphia, Pa.

STUDENT BRANCHES

CHANGES OF ADDRESS

CHU, P. F. (Student, 1909), 31 Inman St., Cambridge, Mass.
CUMPSTON, E. H., Jr. (Student, 1909), 2252 Washington Ave., Cincinnati, O.
GREEN, J. B. (Student, 1909), 4734 Kimbark Ave., Chicago, Ill.
HARKNESS, C. L. (Student, 1910), Association House, Champaign, Ill.
HOLLENBERGER, Theo. J. (Student, 1909), 63 N. Adolph Ave., Akron, O.
ILLMER, G. M. (Student, 1909), 2739 Calvert St., Baltimore, Md.
KUPPATRICK, H. J. (Student, 1909), Roseville, Ill.
LAWRENCE, J. H. (Student, 1909), 3120 Broadway, New York, N. Y.
NYLAND, Evert (Student, 1909), 1428 N. Bouvie St., Philadelphia, Pa.
PETERSON, A. G. (Student, 1909), Lodi, N. Y.
STEINBECK, C. E. (Student, 1909), 1029 N. Hunter St., Stockton, Cal.
STEWART, H. M. (Student, 1910), 2358 Ohio Ave., Cincinnati, O.

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ARMOUR INSTITUTE OF TECHNOLOGY

CUMMINGS, G. F. (Student, 1910), 3360 Prairie Ave., Chicago, Ill.
HATMAN, J. G. (Student, 1910), 3653 Calumet Ave., Chicago, Ill.

BROOKLYN POLYTECHNIC INSTITUTE

BURKE, T. F. (Student, 1910), 125 W. 111th St., New York, N. Y.
HELWIG, Arthur (Student, 1910), 10th Ave. and 70th St., Brooklyn, N. Y.

CORNELL UNIVERSITY

DEXTER, R. L. (Student, 1910), 603 E. Seneca St., Ithaca, N. Y.
KONSTANKEWICZ, M. (Student, 1910), 208 Williams St., Ithaca, N. Y.
LEHMAN, M. G. (Student, 1910), Barnes Hall, Ithaca, N. Y.
MATTHAI, A. M. (Student, 1910), 810 University Ave., Ithaca, N. Y.
ROOS, D. G. (Student, 1910), 105 Highland Pl., Ithaca, N. Y.
WEED, R. W. (Student, 1910), 404 N. Cayuga St., Ithaca, N. Y.

PENNSYLVANIA STATE COLLEGE

HASSLER, Joseph A. (Student, 1910), Alpha Kappa Delta House, Pa. State College, State College, Pa.
HOFFMAN, William S. (Student, 1910), 492 Main Bldg., Pa. State College. State College, Pa.

MATTERN, J. Fred (Student, 1910), Alpha Kappa Delta House, Pa. State College, State College, Pa.

MINSKER, John W. (Student, 1910), 339 McAllister Hall, Pa. State College, State College, Pa.

MORGAN, Henry (Student, 1910), 339 McAllister Hall, Pa. State College, State College, Pa.

PURDY, Donald F. (Student, 1910), 314 E. College Ave., Pa. State College, State College, Pa.

RAHN, Robert M. (Student, 1910), 370 Main Bldg., Pa. State College, State College, Pa.

WHITE, J. Frank (Student, 1910), 132 Beaver Ave., Pa. State College, State College, Pa.

UNIVERSITY OF ILLINOIS

BUTTERS, H. M. (Student, 1910), 210 E. Green St., Champaign, Ill.
BUYERS, D. E. (Student, 1910), 502 E. Green St., Champaign, Ill.

UNIVERSITY OF WISCONSIN

CHRISTIE, H. A. (Student, 1910), 229 W. Gilman St., Madison, Wis.
GRAY, C. F. (Student, 1910), 811 W. Johnson St., Madison, Wis.
SUHS, G. H. (Student, 1910), 225 W. Gilman St., Madison, Wis.
THOMPSON, O. T. (Student, 1910), 225 W. Gilman St., Madison, Wis.

COMING MEETINGS

April–May

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AIR BRAKE ASSOCIATION

May 10–13, Dennisson Hotel, Indianapolis, Ind. Subjects for discussion, and chairmen: Air Brake Instruction, Examination and Rating, Thos. Clegg; Air Pump Piping, Fittings and Connections, George W. Kiehm; Best Arrangement of Air Pump and Main Reservoir Capacity for100-car Train Service, P. J. Langan; Brake Cylinders and Connections to Cylinder Leakage, W. P. Garabrant; Inspection and Cleaning of Triple Valves and Brake Cylinders, C. P. McGinnis; Developments in Air Brakes, W. V. Turner; New York Brake Equipment, T. F. Lyons; Westinghouse Equipment, S. G. Down; Recommended Practice, S. G. Down. Secy., F. M. Nellis, 53 State St., Boston, Mass.

AMERICAN ASSOCIATION ELECTRIC MOTOR MANUFACTURERS

May 18, Newport News, Va. Secy., Frank H. Couch, Hampton.

AMERICAN ASSOCIATION OF LOCAL FREIGHT AGENTS

April 19–22, Mobile, Ala. Secy., G. W. Dennison, Toledo, O.

AMERICAN ELECTROCHEMICAL SOCIETY

May 5–7, Spring Meeting, Pittsburg, Pa. Addresses on the Present Status of Electrochemical Industries; Pittsburg as an Electrochemical Center; the Conservation of Natural Sources of Power. Secy., Dr. J. W. Richards, Lehigh University, South Bethlehem.

AMERICAN EXPOSITION IN BERLIN

June 1–Aug. 31, American Manager, Max Vieweger, 50 Church St., New York.

AMERICAN FOUNDRYMEN'S ASSOCIATION and AMERICAN BRASS-FOUNDERS' ASSOCIATION

May 18–20, joint convention, Cincinnati, O. Secy., A. F. A., Richard Moldenke; A. B. F. A., W. M. Corse.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

March 30–April 1, Charlotte, N. C. Papers: Electric Drive in Textile Mills, A. Milmow; Gas Engines in City Railway and Light Service, E. D. Latta, Jr.; Modifications of Hering's Laws of Furnace Electrodes, A. E. Kennelly; The Proportioning of Electrodes for Furnace Electrodes, Carl Hering; Some Demonstrations of Lightning Phenomena, E. E. F. Creighton; Economics of Hydroelectric Plants, W. S. Lee; A Method of Protecting Insulators on the Lines of the Niagara and Lockport Power Company, L.

C. Nicholson. April 21, San Francisco, Cal. Papers: Economics of a Generator Power System, P. M. Downing; Hydroelectric Developments and Irrigation, J. C. Hays. July 31, annual meeting., 29 W. 39th St., New York. Secy., R. W. Pope, 29 W. 39th St.

AMERICAN MATHEMATICAL SOCIETY

April 30, Columbia University, 150 W. 116th St., New York. Secy., F. N. Cole.

AMERICAN PORTLAND CEMENT MANUFACTURERS

April 12. Secy., Percy H. Wilson, Philadelphia, Pa.

AMERICAN RAILWAY ASSOCIATION

May 18, New York. Secy., W. F. Allen, 24 Park Pl.

AMERICAN RAILWAY INDUSTRIAL ASSOCIATION

May 10, Memphis, Tenn. Secy., Guy L. Stewart, S. W. Ry., St. Louis, Mo.

AMERICAN SOCIETY OF CIVIL ENGINEERS

April 6, 20, 220 W. 57th St., New York. Papers, April 6: New York Tunnel Extension of the Pa. R. R.; The Terminal Station, West, B. F. Cresson, Jr.; The Bergen Hill Tunnels, F. Lavis. Papers, April 20: Federal Investigation of Mine Accidents, Structural Materials and Fuels at Pittsburg Testing Station, H. M. Wilson.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

April 9, St. Louis, Mo., with St. Louis Section, A. I. E. E., and Engineers Club of St. Louis. April 12, 29 West 39th. St., New York. April 27, Auditorium Edison Electric Illuminating Co. of Boston, Boston, Mass., Boston Section, A. I. E. E., and Boston Soc. C. E., coöperating. May 31–June 3, Spring Meeting, Atlantic City, N. J. July 26–29, meeting in Birmingham and London, England. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SUPPLY AND MCHY. MFRS. ASSOC. and SOUTHERN SUPPLY AND MCHY. DEALERS ASSO.

April 5–7, Convention, Seminole Hotel, Jacksonville, Fla.

AMERICAN WATER WORKS ASSOCIATION

April 26–30, annual convention, New Orleans, La. Paper: New Orleans Sewerage and Water Supply Systems, G. C. Earl. Secy., J. M. Diven, 14 George St., Charleston, S. C.

BROOKLYN POLYTECHNIC STUDENT SECTION, AM. SOC. M. E.

April 9. Paper: Engineering and Common Sense, William Kent, Mem. Am. Soc. M. E. Secy., Percy Gianella.

CANADIAN FREIGHT ASSOCIATION

April 14, annual meeting, Montreal. Secy., T. Marshall, Toronto, Ont.

FLORIDA ELECTRIC LIGHT AND POWER ASSOCIATION

April 12, annual meeting, Tampa. Secy., G. I. Doig, Gainesville.

INTERNATIONAL MASTER BOILERMAKERS' ASSOCIATION

May 24-27, New Clifton Hotel, Niagara Falls, Ont. Secy., Harry D. Vought, 95 Liberty St., New York.

INTERNATIONAL RAILWAY FUEL ASSOCIATION

May 23–26, Chicago. Secy., D. B. Sebastian, 327 LaSalle St.

IOWA ELECTRICAL ASSOCIATION SHOW

April 20–21, Sioux City. Secy., W. N. Keiser, Des Moines Electrical Co., Des Moines.

IOWA STREET AND INTERURBAN ASSOCIATION
April 20, 21, Sioux City. Secy:, L. D. Mathes, Dubuque.

MISSOURI ELECTRIC AND GAS ASSOCIATION
April 14–16, Jefferson City. Secy., C. L. Clary, Sikeston.

MODERN SCIENCE CLUB
April 12. Annual election, 125 S. Elliott Pl., Brooklyn, N. Y. Secy., J. A. Donnelly.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS
April 27, 28, annual meeting, Boston. Secy., Dr. C. J. H. Woodbury, Mem.Am.Soc.M.E., Box 3772.

NATIONAL ASSOCIATION OF MANUFACTURERS
May 16–18, New York. Secy., George S. Boudinot, 170 Broadway.

NATIONAL DISTRICT HEATING ASSOCIATION
May, annual meeting, Toledo, Ohio. Secy., A. C. Rogers.

NATIONAL ELECTRIC LIGHT ASSOCIATION
May 23–28, St. Louis, Mo. Secy., Frank H. Tate, Dayton, O.

NATIONAL GAS ASSOCIATION OF AMERICA
May 17–19, Oklahoma City, Okla. Secy., M. W. Walsh, 110 N. Broadway.

NATIONAL MACHINE TOOL-BUILDERS ASSOCIATION
May 24, 25, Spring Convention, Hotel Seneca, Rochester, N. Y. Secy., C. E. Hildreth, Worcester, Mass.

NATIONAL METAL TRADES ASSOCIATION
April 13, 14, annual convention, Hotel Astor, New York.

NEW ENGLAND WATERWORKS ASSOCIATION
April 13, special meeting, Hartford, Conn. June, Providence, R. I. September 14–16, annual convention, Rochester, N. Y. Secy., Willard Kent, Narragansett Pier, R. I.

OHIO SOCIETY OF ENGINEERS
May 19, 20, Cincinnati. Secy., F. E. Sanborn, Ohio State University, Columbus.

PENNSYLVANIA STATE GAS ASSOCIATION
April, Easton. Secy., W. H. Merritt, Lebanon.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS
April 26, West Hall, R. I. School of Design, 8 p.m. Paper: Oxy-Acetylene Welding and Cutting, Henry Cave; May 24, Modern Machine Tools. Secy., Prof. T. M. Phetteplace, Mem.Am.Soc.M.E., 48 Snow St.

SOCIETY OF CHEMICAL INDUSTRY
April 1, annual meeting, New England Section. Secy., Alan Claflin, 88 Broad St., Boston, Mass.

STEVENS ENGINEERING SOCIETY
April 5, 12, 19, 26, Hoboken, N. J. Papers: Theory of Gyroscopic Motion, L. A. Martin, Jr.; Handling Concrete Work, F. B. Gilbreth, Mem.Am.Soc.-M. E.; Notable Examples in Modern Construction, J. C. Ostrup; Development of the New Navy, D. W. Taylor.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
April			
2	Amer. Soc. Hungarian Engineers and Architects	Z. deNemeth	8.30
7	Blue Room Engineering Society	W. D. Sprague	8.00
12	The American Society of Mechanical Engineers	C. W. Rice	8.15
12	Amer. Soc. Engineering Contractors	D. J. Hauer	2.30 8.00
14	Illuminating Engineering Society	P. S. Millar	8.00
15	New York Railroad Club	H. D. Vought	8.15
15	American Institute of Electrical Engineers	R. W. Pope	8.00
19	New York Telephone Society	T. H. Lawrence	8.00
27	Municipal Engineers of City of New York	C. D. Pollock	8.15
29	American Institute of Electrical Engineers	R. W. Pope	8.00

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Members of the Council for 1910

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Alex. C. Humphreys .... New York
Henry G. Stott .... New York

Terms expire at Annual Meeting of 1910

H. L. Gantt .... Pawtucket, R. I.
I. E. Moultrop .... Boston, Mass.
W. J. Sando .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft .... Philadelphia, Pa.
James Hartness .... Springfield, Vt.
H. G. Reist .... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

William H. Wiley .... New York

CHAIRMAN OF THE FINANCE COMMITTEE

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SECRETARY

Calvin W. Rice .... 29 West 39th Street, New York

SPECIAL COMMITTEES

1910

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
A. P. Trautwein
G. T. Voorhees
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
G. M. Basford
F. R. Hutton
D. S. Jacobus
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On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
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On International Standard for Pipe Threads

E. M. Herr, *Chairman*
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Geo. M. Bond
Stanley G. Flagg, Jr.

On Standards for Involute Gears

Wilfred Lewis, *Chairman*
Hugo Bilgram
E. R. Fellows
C. R. Gabriel
Gaetano Lanza

On Power Tests

D. S. Jacobus, *Chairman*
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William Kent
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Albert C. Wood

On Student Branches

F. R. Hutton, Honorary Secretary

On Meetings of the Society in Boston

Ira N. Hollis, *Chairman*
Edward F. Miller
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H. F. J. PORTER (2)
GEO. I. ROCKWOOD (4)
GEO. M. BASFORD (5)

RESEARCH

W. F. M. GOSS (4), *Chairman*
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JAS. CHRISTIE (5)

NOTE—Numbers in parentheses indicate number of years the member is yet to serve.

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1910

On John Fritz Medal

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F. R. Hutton (2)
Chas. Wallace Hunt (3)
Henry R. Towne (4)

On Board of Trustees United Engineering Societies Building

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Fred J. Miller (2)
Jesse M. Smith (3)

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On National Fire Protection Association

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On Joint Committee on Engineering Education

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On Government Advisory Board on Fuels and Structural Materials

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On Advisory Board National Conservation Commission

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Chas. T. Main

On Council of American Association for the Advancement of Science

Alex. C. Humphreys
Fred J. Miller

Note—Numbers in parentheses indicate number of years the member is yet to serve.

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1909

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J. R. Bibbins

SECRETARY
Geo. A. Orrok

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C. B. Rearick

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Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. E. Dudley	F. T. Kennedy
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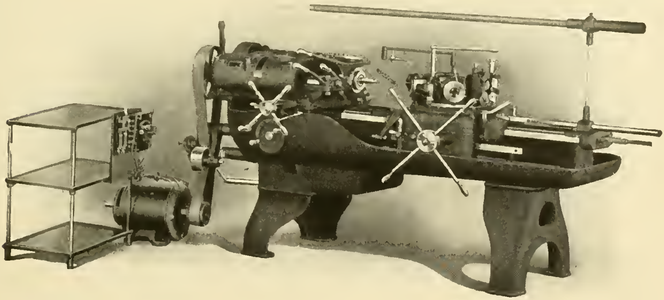
	1910			
Univ. of Maine, Orono, Me.	February 8	....	....	....

SECTION 1

Machine Shop Equipment



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This machine, equipped for chuck work, is described on pages 45 to 85. See also pages 22 to 26.

The machine may be ordered with either the chucking or bar outfit, and supplied later with the other outfit, if for any reason the machine should be changed from bar to chuck work, or *vice versa*. Since the chucking outfit is comparatively inexpensive, it is frequently ordered with the bar outfit of one or more machines of a lot, so that at least one machine may be used on short notice for chuck work.

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